DEVELOPMENT OF MANUAL LIFTING GUIDELINES FOR SRI LANKAN POPULATION

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Degree of Master of Engineering

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Sri Lanka

November 2016

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Thesis submitted in partial fulfillment of the requirements for the degree
Master of Engineering in Manufacturing Systems Engineering

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November 2016

DECLARATION

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ABSTRACT

Restricted work time due to poor occupational health and safety practices take a particularly heavy toll in developing countries, such as Sri Lanka. Work-related musculoskeletal disorders are among the most frequently reported causes of lost or restricted work time. Low back disorder is the major musculoskeletal disorder in most of the industries, where lifting is associated as a major risk factor. Therefore it is important to design manual lifting tasks to not to exceeding the limits of musculoskeletal systems to avoid musculoskeletal disorders. Ergonomists have conducted research on manual material lifting over last few decades to reduce the low back disorders. As a result of above research there are large number assessment lifting tools developed. There is no evidence on validating the above mentioned lifting assessment tools to the Sri Lankan context and also there is no ergonomic guideline or lifting assessment tool developed considering the body sizes of Sri Lankan population. This study would lead to the development of ergonomic guidelines for manual lifting for Sri Lankan population using existing lifting assessment tools.

Revised National Institute for Occupational Safety and Health (NIOSH) Lifting Equation, American Conference of Governmental Industrial Hygienists lifting Threshold Limit Values and Washington Industrial Safety and Health Act Rule Lifting Calculator were identified as key lifting assessment tools. A case study was conducted in a manufacturing plant to check the validity of the above manual lifting assessment tools identified through the literature review. Ergonomic discomfort scale was used as a tool for getting the workers response on above tools. The outputs of all the lifting assessment tools calculated and converted to lifting indexes similar to the lifting index calculated in NIOSH lifting equation. Results of the lifting assessment tools compared with the ergonomic discomfort feedback of the workers who performing lifting tasks. The ergonomic guideline for Sri Lankan population was developed by using the results of above comparison. The developed guideline was validated using a case study. The developed guideline was validated only for male population and future development of manual lifting guideline for Sri Lankan female population is possible.

Keywords: Manual lifting assessment tools, ergonomic guidelines

ACKNOWLEDGEMENTS

For the successful completion of the research and thesis I would like to specially thank Dr. Himan K.G. Punchihewa. He is the only supervisor of the research and guided in various stages of the research by using his expertise knowledge on subject. Also I would like to thank Dr. Ruwan Gopura, Coordinator of Manufacturing Systems Engineering Master degree, for his enthusiastic support and motivation extended towards me in completing this research and all the staff members of the Department of Mechanical Engineering for their assistance. I would also like to specially thank for the management of my manufacturing organization, Supervisors, team leaders and finally participants of the case study for their valuable support to make this research success.

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LIST OF ABBREVIATIONS

Abbreviation	Description
ACGIH	American Conference of Governmental Industrial Hygienists
ILO	International Labour Organization
NIOSH	National Institute of Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
OH&S	Occupational Health and Safety
OHSAS	Occupational Health and Safety Assessment Series
USA	United States of America
WISHA	Washington Industrial Safety and Health Act

1 INTRODUCTION

1.1. Background

The safety and health conditions at work are very different between countries, economic sectors and social groups. Work-related deaths and injuries take a particularly heavy toll in developing countries, such as Sri Lanka where a large part of the population is engaged in hazardous activities. According to the international labour organization, the human cost of this adversity is very high and the economic burden of poor occupational safety and health practices is estimated at 4 per-cent of global Gross Domestic Product each year [1].

Organizations of all kinds are increasingly concerned with achieving and demonstrating sound occupational health and safety (OH&S) performance by controlling their OH&S risks, consistent with their OH&S policy and objectives. They do so in the context of increasingly stringent legislation, the development of economic policies and other measures that foster good OH&S practices, and increased concern expressed by interested parties about OH&S issues [2].

Work-related musculoskeletal disorders (MSDs) are among the most frequently reported causes of lost or restricted work time. According to [3] 916,400 cases on nonfatal occupational injuries and illnesses requiring days away from work reported in USA private industries in 2014. 331,180 cases were involving sprains, strains, tears and 162,720 cases involving back pains in above statistics [3]. The main cause for most of the sprains, strains, tears and back pain cases is manual material handling.

Manual materials handling (MMH) means moving or handling things by lifting, lowering, pushing, pulling, carrying, holding, or restraining [4]. All the above mentioned manual material handling tasks could lead to Low back disorder, sprain, strain and tear but lifting is commonly associated as a major risk factor in the workplace [4].

The management's objective is to improve the productivity in every possible manner and therefore they always try to get maximum output from their workforce. When considering the manual lifting activities management always try to increase the weight and frequency of lifting in order to increase the productivity. However there could be health and safety risks associated with lifting loads heavier than recommended. It is so important to design manual lifting tasks to not to exceeding the limits of musculoskeletal and cardiopulmonary systems to avoid musculoskeletal disorders and chronic injuries [5]. The balance between productivity and ergonomic discomfort level is so significant in industries to avoid additional direct and indirect costs due to poor productivity and as well as cost related to results of poor ergonomic practices. In the workplace, the number and severity of MSDs resulting from physical overexertion, as well as their associated costs, can be substantially reduced by applying ergonomic principles [1].

1.2. Research gap

Ergonomists have conducted researches on manual material lifting over last few decades to reduce the low back disorders and other musculoskeletal disorders. As a result of above researches there were large number assessment methods and tools developed to identify high risk lifting jobs, aim for solutions, and evaluate the effectiveness of potential solutions for lifting. Most of the assessment methods throughout time have been discarded due to different reasons and there are about four major lifting tools currently practiced in the industry [5].

Ergonomists have proven that muscle maximum strength capacity diverges as height varies, indicating that there is a relationship between anthropometry and strength capability. Therefore individuals manual lifting capability is depend on the size of the body of the person performing the lifting task [6]. The human anthropometry varies according to the geographical region. Most of the major lifting assessment tools developed in USA and validated for their population [7].

There is no ergonomic guideline or lifting assessment tool developed in Sri Lanka considering the body sizes of Sri Lankan population. Also there is no evidence on validating the above mentioned lifting assessment tools to the Sri Lankan context. This study would lead to the development of ergonomic guidelines for manual lifting with using existing lifting assessment tools.

1.3. Aim and Objectives

The aim of the research was to develop an ergonomics guideline for manual material handling for the Sri Lankan population. In this pursuit the following objectives were considered.

1. To study existing health and safety standards and ergonomic guidelines for manual lifting
2. To develop ergonomic guidelines for manual lifting in the Sri Lankan context
3. To validate the developed guidelines.

1.4. Methodology

A detailed literature survey was conducted on health and safety standards and ergonomic guidelines for manual material lifting. In this review the search for relevant literature was approached with a rather broad perspective. Keywords were occupational health and safety and manual material handling guidelines with a number of synonyms combined with such as standards, Sri Lankan standards, accidents, risk, hazard, ergonomics, musculoskeletal disorder, manual lifting, assessment tools and work environment. In addition, a number of delimitation criteria were used. International databases were searched and collected the reference hits. Initially irrelevant references such as lack of focus on occupational health and safety and manual material handling were excluded. Then shortlisted relevant research papers by reading the abstract. Then shortlisted references were reviewed to compare and contrast the available manual lifting guidelines and assessment tools and identify research gaps in manual material lifting guideline especially focusing on the Sri Lankan context.

An ergonomic guideline was developed for manual lifting considering the Sri Lankan population. A case study was conducted in a manufacturing plant to check the validity of existing manual lifting assessment tools identified through the literature review. Revised National Institute for Occupational Safety and Health (NIOSH) Lifting Equation (1991), American Conference of Governmental Industrial Hygienists (ACGIH) lifting Threshold Limit Values and Washington Industrial Safety and Health Act (WISHA) Rule Lifting Calculator were used as lifting assessment tools and ergonomic discomfort scale was used as a tool for getting the workers response on above tools. Results of the lifting assessment tools compared with the ergonomic discomfort feedback of the workers who performing lifting tasks. The ergonomic guideline for Sri Lankan population was developed by using the results of above comparison.

The developed guideline was validated using a case study conducted in the same manufacturing plant conducted the previous case study. The recommended weight limit calculated using the developed guidelines and 12 jobs were designed for 6 manual lifting zones. The case study was conducted for the developed 12 jobs and collected the ergonomic discomfort feedback response for the each job. The ergonomic discomfort values were compared with the developed guideline and the guideline was validated.

1.5. Chapter introduction

Chapter 2 broadly discusses about the literature review and the findings of the literature review. It discusses about the lifting assessment tools and their limitations. A case study was conducted to check the validity of the international manual lifting assessment tools to the Sri Lankan population and details about the case study and the findings were discussed in chapter 3. Chapter 4 elaborates the development of the Sri Lankan guideline and Chapter 5 discuss about the validation of the Guideline to the Sri Lankan population. Chapter 6 presents a discussion on the findings and results of the entire project and recommendations for future work. Conclusions are presented at chapter 7 of this thesis.

2 LITERATURE REVIEW

2.1. Occupational health and safety management systems

Occupational health and safety management systems provide a systematic way of managing health and safety with continual improvement [1]. There are several occupational health and safety management systems developed in the world.

2.1.1. OSHAS 18001: 2007

❖ **Introduction**

OSHAS 18001: 2007 is the most widely used occupational health and safety standard in the world. The OHSAS 18001:2007 standard was developed by British standard institute and currently it is used in all over the world. The OHSAS Standards covering OH&S management are intended to provide organizations with the elements of an effective OH&S management system that can be integrated with other management requirements and help organizations achieve OH&S and economic objectives. These standards, like other International Standards, are not intended to be used to create non-tariff trade barriers or to increase or change an organization's legal obligations. This OHSAS Standard specifies requirements for an OH&S management system to enable an organization to develop and implement a policy and objectives which take into account legal requirements and information about OH&S risks. It is intended to apply to all types and sizes of organizations and to accommodate diverse geographical, cultural and social conditions [8].

The success of the system depends on commitment from all levels and functions of the organization, and especially from top management. A system of this kind enables an organization to develop an OH&S policy, establish objectives and processes to achieve the policy commitments, take action as needed to improve its performance and demonstrate the conformity of the system to the requirements of this OHSAS Standard. The overall aim of this OHSAS Standard is to support and promote good OH&S practices, in balance with socio-economic needs [8]. It should be noted that many of the requirements can be addressed concurrently or revisited at any time.

The second edition of this OHSAS Standard is focused on clarification of the first edition, and has taken due consideration of the provisions of ISO 9001, ISO14001, ILO-OSH, and other OH&S management system standards or publications to enhance the compatibility of these standards for the benefit of the user community [8].

There is an important distinction between this OHSAS Standard, which describes the requirements for an organization's OH&S management system and can be used for certification/registration and/or self-declaration of an organization's OH&S management system, and a non-certifiable guideline intended to provide generic assistance to an organization for establishing, implementing or improving an OH&S management system [8], [9]. OH&S management encompasses a full range of issues, including those with strategic and competitive implications. Demonstration of successful implementation of this OHSAS Standard can be used by an organization to assure interested parties that an appropriate OH&S management system is in place system [8], [9].Those organizations requiring more general guidance on a broad range of OH&S management system issues are referred to OHSAS 18002. Any reference to other International Standards is for information only.

The OHSAS Standard is based on Deming's TQM Cycle system [8], [9]. It can be briefly described as follows.

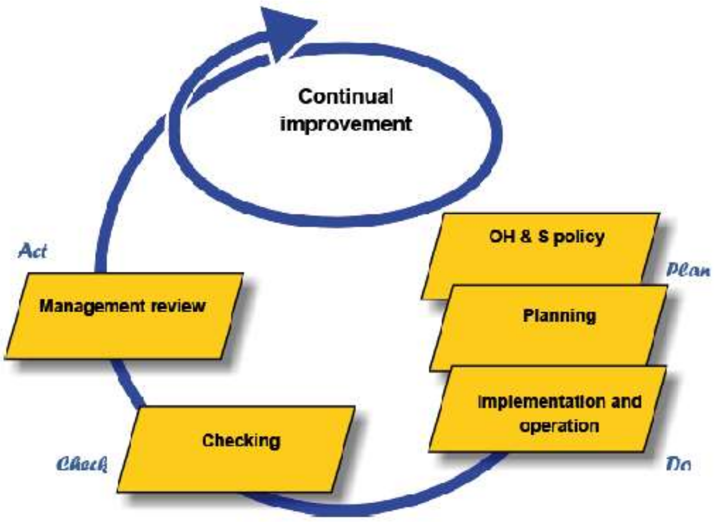


Figure 2.1: OH&S management system model for OHSAS Standard

Source: [10]

- ✓ Plan: establish the objectives and processes necessary to deliver results in accordance with the organization's OH&S policy.
- ✓ Do: implement the processes.
- ✓ Check: monitor and measure processes against OH&S policy, objectives, legal and other requirements, and report the results.
- ✓ Act: take actions to continually improve OH&S performance.

❖ **OH&S management system requirements**

The organization shall establish, document, implement, maintain and continually improve an OH&S management system in accordance with the requirements of this OHSAS Standard and determine how it will fulfill these requirements. The organization shall define and document the scope of its OH&S management system [9].

❖ **Hazard identification, risk assessment and determining controls**

The organization shall establish, implement and maintain a procedure(s) for the ongoing hazard identification, risk assessment, and determination of necessary controls. The procedure(s) for hazard identification and risk assessment [9] shall take into account:

a) Routine and non-routine activities;

b) Activities of all persons having access to the workplace (including contractors and visitors);

c) Human behavior, capabilities and other human factors;

d) Identified hazards originating outside the workplace capable of adversely affecting the health and safety of persons under the control of the organization within the workplace;

e) Hazards created in the vicinity of the workplace by work-related activities under the control of the organization;

f) Infrastructure, equipment and materials at the workplace, whether provided by the organization or others;

g) Changes or proposed changes in the organization, its activities, or materials;

h) Modifications to the OH&S management system, including temporary changes, and their impacts on operations, processes, and activities;

i) Any applicable legal obligations relating to risk assessment and implementation of necessary controls

j) The design of work areas, processes, installations, machinery/equipment, operating procedures and work organization, including their adaptation to human capabilities.

The organization's methodology for hazard identification and risk assessment shall:

a) Be defined with respect to its scope, nature and timing to ensure it is proactive rather than reactive; and

b) Provide for the identification, prioritization and documentation of risks, and the application of controls, as appropriate.

For the management of change, the organization shall identify the OH&S hazards and OH&S risk associated with changes in the organization, the OH&S management system, or its activities, prior to the introduction of such changes.

The organization shall ensure that the results of these assessments are considered when determining controls. When determining controls, or considering changes to existing controls, consideration shall be given to reducing the risks according to the following hierarchy:

a) Elimination;

b) Substitution;

c) Engineering controls;

d) signage/warnings and/or administrative controls;

e) Personal protective equipment.

The organization shall document and keep the results of identification of hazards, risk assessments and determined controls up-to-date.

The organization shall ensure that the OH&S risks and determined controls are taken into account when establishing, implementing and maintaining its OH&S management system.

- **Legal and other requirements**

The organization shall establish, implement and maintain a procedure(s) for identifying and accessing the legal and other OH&S requirements that are applicable to it. The organization shall ensure that these applicable legal requirements and other requirements to which the organization subscribes are taken into account in establishing, implementing and maintaining its OH&S management system. The organization shall keep this information up-to-date. The organization shall communicate relevant information on legal and other requirements to persons working under the control of the organization, and other relevant interested parties [9].

- **Performance measurement and monitoring**

The organization shall establish, implement and maintain a procedure(s) to monitor and measure OH&S performance on a regular basis. This procedure(s) shall provide for:

a) both qualitative and quantitative measures, appropriate to the needs of the organization;

b) monitoring of the extent to which the organization's OH&S objectives are met;

c) monitoring the effectiveness of controls (for health as well as for safety);

d) proactive measures of performance that monitor conformance with the OH&S programme(s), controls and operational criteria;

e) reactive measures of performance that monitor ill health, incidents (including accidents, near-misses, etc.), and other historical evidence of deficient OH&S performance;

f) recording of data and results of monitoring and measurement sufficient to facilitate subsequent corrective action and preventive action analysis.

If equipment is required to monitor or measure performance, the organization shall establish and maintain procedures for the calibration and maintenance of such equipment, as appropriate. Records of calibration and maintenance activities and results shall be retained.

2.1.2. ILO Guidelines on OSH Management Systems (ILO-OSH 2001)

❖ **INTRODUCTION**

ILO Guidelines on OSH Management Systems (ILO-OSH 2001) is an occupational health and safety guidelines developed by international labour organization. ILO-OSH 2001 provides a unique international model, compatible with other management system standards and guides. It is not legally binding and not intended to replace national laws, regulations and accepted standards. It reflects ILO values such as tripartism and relevant international standards including the Occupational Safety and Health Convention, 1981 (No.155) and the Occupational Health Services Convention, 1985 (No. 161). Its application does not require certification, but it does not exclude certification as a means of recognition of good practice if this is the wish of the country implementing the Guidelines [1].

The ILO Guidelines encourage the integration of OSH-MS with other management system and state that OSH should be an integral part of business management. While integration is desirable, flexible arrangements are required depending on the size and type of operation. Ensuring good OSH performance is more important than formality of integration. As well as this, ILO-OSH 2001 emphasizes that OSH should be a line management responsibility at the organization, the guidelines [11] provide guidance for implementation on two levels

- national level(Chapter 2) and

- organizational level(Chapter 3).

- **Guidance for national occupational safety and health management system framework**

At the national level, they provide for the establishment of a national framework for occupational safety and health (OSH) management systems, preferably supported by national laws and regulations. Action at national level includes the nomination of (a) competent institution(s) for OSH-MS, the formulation of a coherent national policy and the establishment of a framework for an effective national application of ILO-OSH 2001, either by means of its direct implementation in organizations or its adaptation to national conditions and practice (by national guidelines) and specific needs of Organizations in accordance with their size and nature of activities (by tailored guidelines).

The National Policy for OSH-MS should be formulated by competent institution(s) in consultation with employers' and workers' organizations, and should consider:

- Promotion of OSH-MS as part of overall management
- Promote voluntary arrangements for systematic OSH improvement
- Avoid unnecessary bureaucracy, administration and costs
- Support by labour inspectorate, safety and health and other services [11], [12].

The functions and responsibilities of implementing institutions should be clearly defined as well. Figure 2.2 of the Guidelines describes the elements of the national framework for OSH managements systems. It shows the different ways in which ILO-OSH 2001 may be implemented in a member State.

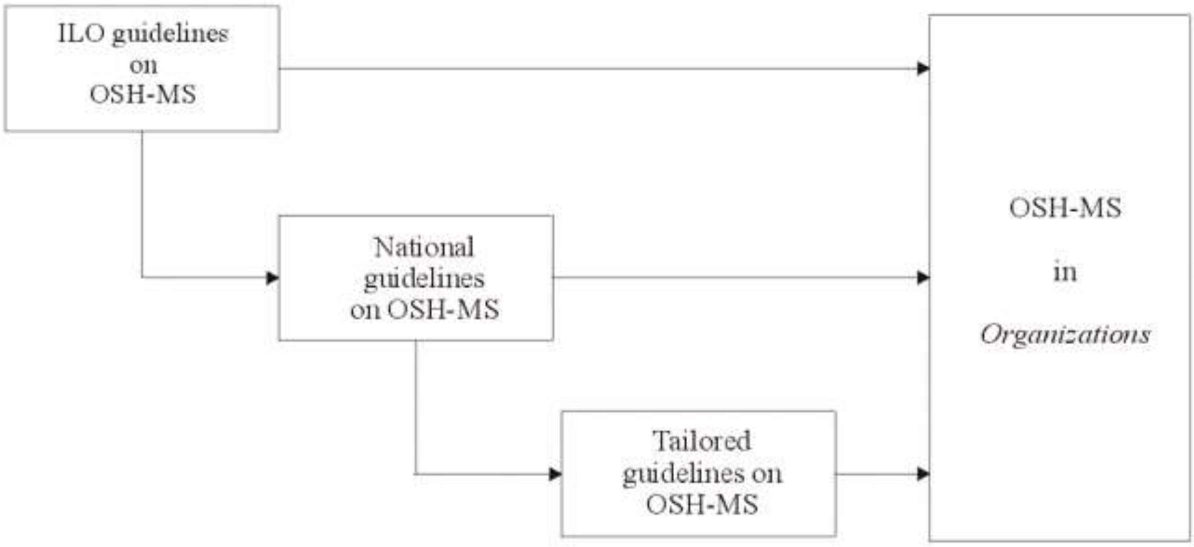


Figure 2.2: Elements of the national framework for OSH managements systems
Source: [12]

- **Guidance for occupational safety and health management system in an organization**

Chapter 3 of ILO-OSH 2001 deals with the occupational safety and health management system at the organizational level. The Guidelines stress that compliance to national laws and regulations are the responsibility of the employer. ILO-OSH 2001 encourages the integration of OSH management system elements into overall policy and management arrangements, as well as stressing the importance that at organizational level, OSH should be a line management responsibility, and should not be seen as a task for OSH departments and/or specialists.

The OSH management systems in the organization has five main sections which follow the internationally accepted Deming cycle of Plan-Do-Check-Act, which is the basis to the “system” approach to management. These sections are namely Policy, Organizing, Planning and implementation, Evaluation and Action for improvement Policy contains the elements of OSH policy and worker participation. It is the basis of the OSH management system as it sets the direction for the organization to follow. Organizing contains the elements of responsibility and accountability, competence and training, documentation and communication [13]. It makes sure that the management structure is in place, as well as the necessary responsibilities allocated for delivering the OSH policy. Planning and implementation contains the elements of initial review, system planning, development and implementation, OSH objectives and hazard prevention [13]. Through the initial review, it shows where the organization stands concerning OSH, and uses this as the baseline to implement the OSH policy. Evaluation contains the elements of performance monitoring and measurement, investigation of work-related injuries, ill-health, diseases and incidents, audit and management review. It shows how the OSH management system functions and identifies any weaknesses that need improvement. It includes the very important element of auditing, which should be undertaken for each stage. Persons independent of the activity being audited should conduct audits. This does not necessarily mean third party auditors. Action for improvement includes the elements of preventive and corrective action and continual improvement. It implements the necessary preventive and corrective actions identified by the evaluation and audits carried out. It also emphasizes the need for continual improvement of OSH performance through the constant development of policies, systems and techniques to prevent and control work-related injuries, ill-health, diseases and incidents [11], [12].

2.1.3. OSHA STANDARDS

- **INTRODUCTION**

OSHA standards are the main occupational health and safety standards used in USA. Occupational Safety and Health Administration (OSHA), a national public health agency dedicated to the basic proposition that no worker should have to choose between their life and their job was created in 1970 [14].

OSHA is committed to protecting workers from toxic chemicals and deadly safety hazards at work, ensuring that vulnerable workers in high-risk jobs have access to critical information and education about job hazards, and providing employers with vigorous compliance assistance to promote best practices that can save lives.

OSHA standards are rules that describe the methods employers are legally required to follow to protect their workers from hazards. Before OSHA can issue a standard, it must go through a very extensive and lengthy process that includes substantial public engagement, notice and comment. The agency must show that a significant risk to workers exists and that there are feasible measures employers can take to protect their workers.

Construction, General Industry, Maritime, and Agriculture standards protect workers from a wide range of serious hazards. These standards limit the amount of hazardous chemicals workers can be exposed to, require the use of certain safe practices and equipment, and require employers to monitor certain workplace hazards.

Examples of OSHA standards include requirements to provide fall protection, prevent trenching cave-ins, prevent exposure to some infectious diseases, ensure the safety of workers who enter confined spaces, prevent exposure to such harmful substances as asbestos and lead, put guards on machines, provide respirators or other safety equipment, and provide training for certain dangerous jobs[14].

Employers must also comply with the General Duty Clause of the OSH Act. This clause requires employers to keep their workplaces free of serious recognized hazards and is generally cited when no specific OSHA standard applies to the hazard [13], [14].

- **Rights and responsibilities under OSHA law**

Employers have the responsibility to provide a safe workplace. Employers MUST provide their workers with a workplace that does not have serious hazards and must follow all OSHA safety and health standards. Employers must find and correct safety and health problems. OSHA further requires that employers must first try to eliminate or reduce hazards by making feasible changes in working conditions rather than relying on personal protective equipment such as masks, gloves, or earplugs. Switching to safer chemicals, enclosing processes to trap harmful fumes, or using ventilation systems to clean the air are examples of effective ways to eliminate or reduce risks[13],[14].

- ❖ **Employers responsibilities**

- Inform workers about chemical hazards through training, labels, alarms, color-coded systems, chemical information sheets and other methods.
- Provide safety training to workers in a language and vocabulary they can understand.
- Keep accurate records of work-related injuries and illnesses.
- Perform tests in the workplace, such as air sampling, required by some OSHA standards.
- Provide required personal protective equipment at no cost to workers.
- Provide hearing exams or other medical tests required by OSHA standards.
- Post OSHA citations and injury and illness data where workers can see them.
- Notify OSHA within eight hours of a workplace fatality or when three or more workers are hospitalized
- Prominently display the official OSHA Job Safety and Health – It’s the Law poster that describes rights and responsibilities under the OSH Act.
- Not retaliate or discriminate against workers for using their rights under the law, including their right to report a work-related injury or illness [13], [14].

- ❖ **Workers’ rights**

According to [13] and [14]

- Working conditions that do not pose a risk of serious harm.
- File a confidential complaint with OSHA to have their workplace inspected.
- Receive information and training about hazards, methods to prevent harm, and the OSHA standards that apply to their workplace. The training must be done in a language and vocabulary workers can understand.
- Receive copies of records of work-related injuries and illnesses that occur in their workplace.
- Receive copies of the results from tests and monitoring done to find and measure hazards in their workplace.
- Receive copies of their workplace medical records.
- Participate in an OSHA inspection and speak in private with the inspector.

- File a complaint with OSHA if they have been retaliated or discriminated against by their employer as the result of requesting an inspection or using any of their other rights under the OSH Act.
- File a complaint if punished or discriminated against for acting as a “whistleblower” under the 21 additional federal laws for which OSHA has jurisdiction.

❖ **OSHA enforcement activities**

Enforcement plays an important part in OSHA’s efforts to reduce workplace injuries, illnesses, and fatalities. When OSHA finds employers who fail to uphold their safety and health responsibilities, the agency takes strong, decisive actions.

Inspections are initiated without advance notice, conducted using on-site or telephone and facsimile investigations, performed by highly trained compliance officers and scheduled based on the following priorities:

- Imminent danger;
- Catastrophes – fatalities or hospitalizations;
- Worker complaints and referrals;
- Targeted inspections – particular hazards, high injury rates; and
- Follow-up inspections.

Current workers or their representatives may file a written complaint and ask OSHA to inspect their workplace if they believe there is a serious hazard or that their employer is not following OSHA standards [13], [14]. Workers and their representatives have the right to ask for an inspection without OSHA telling their employer who filed the complaint. It is a violation of the OSH Act for an employer to fire, demote, transfer or in any way discriminate against a worker for filing a complaint or using other OSHA rights [13], [14].

When an inspector finds violations of OSHA standards or serious hazards, OSHA may issue citations and fines. A citation includes methods an employer may use to fix a problem and the date by which the corrective actions must be completed.

Employers have the right to contest any part of the citation, including whether a violation actually exists. Workers only have the right to challenge the deadline by which a problem must be resolved. Appeals of citations are heard by the independent Occupational Safety and Health Review Commission (OSHRC).

2.1.4. ISO standard for occupational health and safety

ISO has started to develop an International Standard for occupational health and safety (OH&S). The much-awaited standard will provide governmental agencies, industry, and other affected stakeholders with effective, usable guidance for improving worker safety in countries around the world. The work will be overseen by ISO Project Committee (PC) 283, Occupational health and safety management systems requirements [15].

The secretariat of ISO/PC 283 has been assigned to BSI, the British Standards Institution, and its first meeting was held on 21-25 October 2013 in London, United Kingdom. The ISO project committee is tasked with transforming OHSAS 18001 (the OH&S management system requirements) into an ISO standard [15].

The ISO project committee brings together experts and interested stakeholders in OH&S management. The committee's job is to develop a standard following the generic management system approaches pioneered by the likes of ISO 9001:2008 for quality management or ISO 14001:2004 for environmental management and since applied to other objectives [15]. The standard currently in draft stage and will be available for public on end of 2017[16].

2.1.5. Occupational health and safety standards in Sri Lanka

- **Introduction**

The most popular occupational health and safety standard in Sri Lanka is SLS OHAS 18001:2007 and is a direct adoption of OHSAS 18001: 2007. The adoption of OHSAS 18001: 2007 is reproduced with the permission of BSI OHSAS project group under the license number 2007JK0078 [8].

It became the most popular occupational health and safety standard in Sri Lanka because OHSAS 18001 has been developed to be compatible with the ISO

9001:2000 (Quality) and ISO 14001:2004 (Environmental) management systems standards, in order to facilitate the integration of quality, environmental and occupational health and safety management systems by organizations, should they wish to do so. Also it is compatible with the recommendations of ILO-OSH guidelines [8].

After realizing the need for wider coverage and taking on the responsibility of the State to ensure a safe and non-exploitative work environment for all Sri Lankans, the Ministry of Labour Relations and Manpower has established the National Institute of Occupational Safety and Health to commit better working conditions for all people, through increasing awareness of and adherence to proper health and safety measures.

- **National Institute of Occupational Safety and Health**

The National Institute of Occupational Safety and Health was established on 28th April 2005, under the Ministry of Labour and Labour Relations Sri Lanka [9]. Their activities include the dissemination of update information, advisory and consultancy services, educate and train employers, employees and all other categories of people who will benefit from such training [17].

Strategic Goals and Objectives of NIOSH

According to [17] the goals of NIOSH are:

- ✓ to advice the Government in the formulation of a national policy on Occupational safety & health & on the working environment both of employers & employees taking into consideration the nature of the occupation & safety of the employers & Employ.
- ✓ to advice the Government on measures required for the prevention of accidents and injuries relating, to Occupation at work places;
- ✓ to conduct, undertake and assist in investigations, study programs, surveys and research in the field of Occupational safety and health

- ✓ to provide advisory services to any institution or person on the correct use of equipment, hazardous substances, physical, chemical or biological agents or products or any other hazards;
- ✓ to educate and provide necessary training to employees, occupiers, workers or any other person required of knowledge and training in occupational safety and health and related subjects either in collaboration with any other institution or university in Sri Lanka or abroad, or by the Institute and award certificates or diplomas on completion of such education or training;
- ✓ to provide required services on the correct use of equipment, hazardous substances, physical, chemical, biological agents or product and psychosocial hazards and avoidance of known hazards;
- ✓ to advise the Minister on legislative requirements with regard to standards ,codes, practices and guidelines in matters relating to occupational safety and health;
- ✓ to evaluate and determine the work process, the substances and agents, the exposure to which is be prohibited, limited or made subject to supervision;
- ✓ to undertake or collaborate in the collection, preparation, dissemination and publishing of information relating to occupational safety and health;
- ✓ to organize or to sponsor conferences, seminars, workshops, symposiums or such other similar programs and publish papers in connection with occupational safety and health;
- ✓ to co-ordinate inter-ministerial projects, programs and activities on occupational safety and health;
- ✓ to establish and maintain libraries and laboratories for the purpose of promoting and furthering of the practice of occupational safety and health;
- ✓ to develop research and special laboratories;
- ✓ to liaise and establish links and networks with relevant National and International Institutions, Universities or any other organizations in the field of occupational safety and health; and
- ✓ to establish national standards in the field of Occupational safety and health.

2.2. Manual Material Handling

Pushing, pulling, holding, carrying, lowering and lifting tasks, commonly known as MMH activities [4], are present in many manufacturing and service industries in different magnitudes. Even though revolutionary technologies such as automation have reduced exposure in some MMH tasks, there are many other tasks that for now machines cannot replace. Today, low-back disorders (LBD), sprain, strain and tear are the top musculoskeletal disorder among several industries [5].

2.3. Manual lifting

There are different sources that could lead to LBD, sprain, strain and tear but lifting is commonly associated as a major risk factor in the workplace [18]. Researchers have developed numerous assessment methods to identify high-risk jobs, aim for solutions, and evaluate the effectiveness of potential solutions for lifting. Many assessment methods throughout time have been discarded for different reasons, oftentimes because new findings through research discovered new relevant factors that those tools didn't take into account, in addition to validity and accuracy issues [19],[7]. Currently four major lifting tools are typically used by ergonomists:

- ✓ Revised National Institute for Occupational Safety and Health(NIOSH)Lifting Equation (1991) [20]
- ✓ American Conference of Governmental Industrial Hygienists (ACGIH) lifting Threshold Limit Values [21]
- ✓ Liberty Mutual Lifting Tables, Liberty Mutual Manual Material Handling Tables [22]
- ✓ Washington Industrial Safety and Health Act (WISHA) Ergonomics Rule Lifting Calculator [23]
- ✓ ISO 11228-1:2003 standard- Ergonomics - Manual handling - Part 1: Lifting and carrying [24], [25]

2.3.1. NIOSH Lifting Equation

The NIOSH Lifting Equation is a tool used by occupational health and safety professionals to assess the manual material handling risks associated with lifting and lowering tasks in the workplace. This equation considers job task variables to determine safe lifting practices and guidelines. The primary result of the NIOSH lifting equation is the Recommended Weight Limit (RWL), which defines the maximum acceptable weight (load) that nearly all healthy employees could lift over the course of an 8 hour shift without increasing the risk of musculoskeletal disorders (MSD) to the lower back [26].

In addition, a Lifting Index (LI) is calculated to provide a relative estimate of the level of physical stress and MSD risk associated with the manual lifting tasks evaluated. A Lifting Index value of less than 1.0 indicates a nominal risk to healthy employees. A Lifting Index of 1.0 or more denotes that the task is high risk for some fraction of the population. As the LI increases, the level of low back injury risk increases correspondingly. Therefore, the goal is to design all lifting jobs to accomplish a LI of less than 1.0. [26].

The NIOSH lifting equation always uses a load constant (LC) of 23 kg, which represents the maximum recommended load weight to be lifted under ideal conditions. From that starting point, the equation uses several task variables expressed as coefficients or multipliers (In the equation, M = multiplier) that serve to decrease the load constant and calculate the RWL for that particular lifting task.

NIOSH Lifting Equation:

$$RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM$$

$$\text{Lifting Index (LI)} = \text{Weight} / RWL$$

$$LC = 23 \text{ kg}$$

$$HM = 25/H, \text{ (H in cm)}$$

$$VM = 1-(0.003 \ |V-75|), \text{ (V in cm)}$$

$$DM = .82 + (4.5/D), \text{ (D in cm)}$$

$$AM = 1- 0.0032A, \text{ (A in degrees)}$$

FM is calculated from Table in Appendix1.

Coupling –

Good – Optimal design containers with handles of optimal design, or irregular objects where the hand can be easily wrapped around the object.

Fair – Optimal design containers with handles of less than optimal design, optimal design containers with no handles or cut-outs, or irregular objects where the hand can be flexed about 90°.

Poor – Less than optimal design container with no handles or cut-outs, or irregular objects that are hard to handle and/or bulky (e.g. bags that sag in the middle).

Table 2.1: Coupling Multiplier for NIOSH Lifting Equation

C = Grasp	**CM Factor:**	
	V<75cm	**V>75 cm**
Good (handles)	1.00	1.00
Fair	1.00	0.95
Poor	0.90	0.90

Source: [4]

Where

- LC- Load constant
- HM – Horizontal multiplier
- VM - Vertical multiplier
- DM - Distance multiplier
- AM- Asymmetric multiplier
- FM- Frequency multiplier
- CM- Coupling multiplier

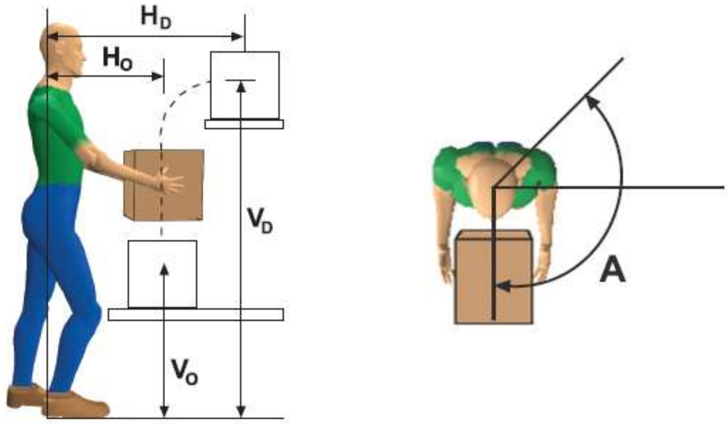


Figure 2.3: Object locations and asymmetry relative to body

Source [26]

Task variables needed to calculate the RWL:

- H = Horizontal location of the object relative to the body
- V = Vertical location of the object relative to the floor
- D = Distance the object is moved vertically
- A = Asymmetry angle or twisting requirement
- F = Frequency and duration of lifting activity
- C = Coupling or quality of the workers grip on the object

2.3.2. ACGIH Lifting Threshold Limit Value (TLV)

In 2001, the American Conference of Governmental Industrial Hygienists released a new lifting assessment method known as the ACGIH Lifting Threshold Limit Values (TLV). It was aimed to provide guidelines to protect virtually any individual when the lifting load is below the TLV within a certain duration, frequency, and horizontal and vertical location of the task, protecting the individual from work-related shoulder and/or low back disorders [5]. If the TLV is exceeded, changes in the work design should be applied such that the load weight lifted falls below the TLV weight.

The ACGIH Lifting TLV assessment method consists of a set of three tables that takes into account the weight of the object, horizontal and vertical location of the object to be lifted at the origin, repetition, and duration of the lifting. In each table are 12 zones; four zones for the vertical height (floor to mid-shin, mid-shin to knuckle, knuckle to shoulder, and shoulder to reach limit) and three horizontal distance zones (close, intermediate and extended). Figure 2.3 gives more detail of the twelve zones [5], [21].

The strengths of this method are that is quick and easy to use: Its format translates relatively complex data into a quick and easy to use assessment and interpretation of the results, helping the user when the TLV is exceeded to consider job redesign strategies. On the other hand, these lifting tables are limited to two-handed mono-lifting tasks with a maximum torso asymmetry of 30 degrees away from the sagittal plane. If any of the following conditions are present, professional judgment should be applied either to reduce the recommended weight limits or to propose a task redesign [5]:

- ✓ Lifting frequency exceeds 360 lifts per hour;
- ✓ Asymmetry greater 30 degrees (rotation in the sagittal plane);
- ✓ Lifting task duration greater than eight hours per day;
- ✓ One-handed lifting;
- ✓ Body posture different from standing, such as kneeling, seated, crouching, restricted headroom;
- ✓ Working conditions under high temperatures and/or humidity (Note: ACGIH also provides Heat Stress and Stain TLVs which should be assessed before using this Method);
- ✓ Lifting unbalanced objects (anything that shifts the center of mass while lifting such as liquids, people, animals);
- ✓ Unstable footing (unable to hold the body with both feet while lifting such as slippery floor, unsteady ground/ or surface);
- ✓ Poor hand coupling (no handles, cut-outs, poor hand holds, or other grasping points).

T.E Bernard developed a modified version for ACGIH Lifting TLV tables named as “additional risk – Lower Screening Limit”. These tables may be used when there is any limitation, except for lifting frequencies that exceed 360 lifts per hour, asymmetry over 30 degrees, or lifting task over eight hours per day, where professional judgment has to be made [29]. However, no validation of these modified ACGIH tables has been performed and in its 2009 ACGIH"s Threshold Limit Values and Biological Exposure Indices book, these additional tables were not included [5].

Another limitation of this method is it is not suitable if other manual material handling, pushing, pulling, and/or carrying, activities are being performed while lifting. This assessment method does not predict injuries, does not consider individual factors such as gender, age, habits (e.g. smoking), or medical history. Additionally, this method, when was developed, only considered the lift origin and not the final destination. In 2007, the ACGIH suggested that if the load is placed in a controlled manner (i.e. slowly or consciously placed), the TLV can be estimated in the same manner as at the origin, and to use the lowest TLV among them. The challenge then becomes deciding when an uncontrolled placement of the load is present [5].

Finally, this assessment method doesn't explain or address what happens when the final destination of the object is different from its origin. To use this method, the weight of the object(s) to be lifted must be known, a tape measure used to measure the horizontal and vertical locations, and task information such as frequency and duration must be determined. The procedure to determine the TLV is as follows:

1. Determine task duration and lifting frequency of the task.
2. Select the proper TLV table. See Appendices 2-5
3. Identify the lifting zone height according to the initial position of the hand, and the horizontal location of the lift (midpoint between the hands compared to midpoint between the ankles).
4. Determine the corresponding zone, then compare the lifted weight against the maximum recommended TLV and report the findings. If the lifted weight exceeds the TLV, an ergonomic intervention should be suggested and implemented such that the weight is less than the TLV.

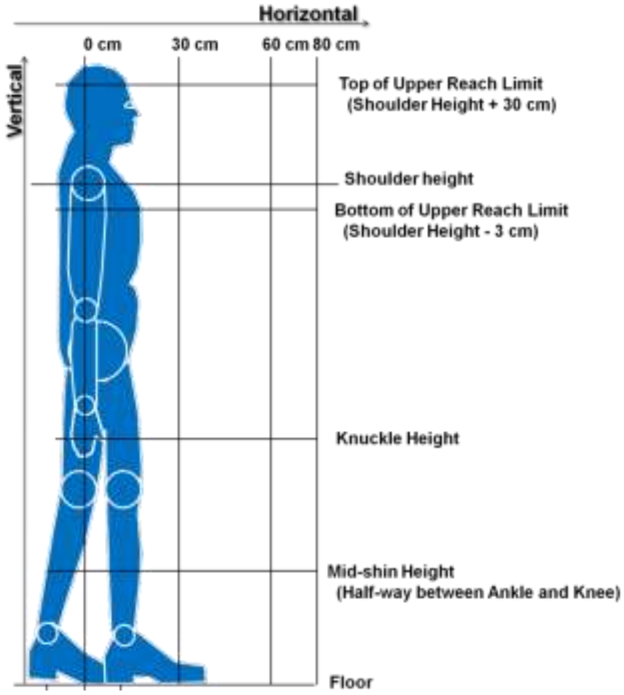


Figure 2.4: Vertical and horizontal zones

Source: [5]

2.3.3. Liberty Mutual lifting Tables (Snook tables)

Liberty Mutual Manual Materials Handling Tables provide both the male and female population percentages capable of performing manual material handling tasks without over exertion, rather than maximum acceptable weights and forces. Since the late 1970's, Liberty Mutual Group Loss Prevention field organization has been analyzing and evaluating lifting, lowering, pushing, pulling and carrying tasks using "Psychophysical Tables. These Tables are based on research by Drs. Stover Snook and Vincent Ciriello at the Liberty Mutual Research Institute for Safety. Their research used psychophysical methodology and provided important information about capability and limitations of workers and design of manual handling tasks to reduce low back disability [21].

These Tables were developed with the goal of controlling costs associated with manual handling operations. These costs can be attributed to high low back disability costs, reduced productivity and quality due to poor job design. These Tables provide the user with an objective risk assessment of a problem manual handling job and the foundation on which to build a solution by:

1) helping recognize risk factors associated with manual handling activity and,
2) helping make good business decisions on implementing cost effective ergonomic solutions that offer the highest degree of control.

When a mixture of males and females are doing the task, the task should be designed so that it is acceptable to at least 75 per cent of the female population, which would make it acceptable to more than 90 per cent of the male population. Any task that cannot be performed by at least 75 percent of the total population should be considered for MSD prevention controls and redesign [28].

Lifting tasks should be evaluated in following categories using relevant tables.

- ✓ Female - Lifting Task Ending Below Knuckle Height (<28")
- ✓ Male - Lifting Task Ending Below Knuckle Height (<31")
- ✓ Female - Lifting Task Ending Between Knuckle Height (≥28") & Shoulder Height (≤53")
- ✓ Male - Lifting Task Ending Between Knuckle Height (≥31") & Shoulder Height (≤57")
- ✓ Female - Lifting Task Ending Above Shoulder Height (>53")
- ✓ Male - Lifting Task Ending Above Shoulder Height (>57")

2.3.4. Washington Industrial Safety and Health Act Ergonomics Rule Lifting Calculator (WISHA Lifting Calculator)

Developed by the Washington State Department of Labor and Industries, this lifting calculator is very simple in design and application. This ergonomic assessment tool is an adaptation of the NIOSH Lifting Equation, which is based on scientific research on the primary causes of work-related back injuries. This calculator can be used to perform simple ergonomic risk assessments on a wide variety of manual lifting and lowering tasks, and can be also used as a screening tool to identify lifting tasks which should be analyzed further using the more comprehensive NIOSH Lifting Equation.

Following data required for data analyzing in WISHA lifting calculator.

- Weight of objects the employee lifts.
- Location or posture when employee performs lift.
- Frequency of lifting – number of times employee performs lift.
- Duration of lifting – number of hours per day spent lifting.

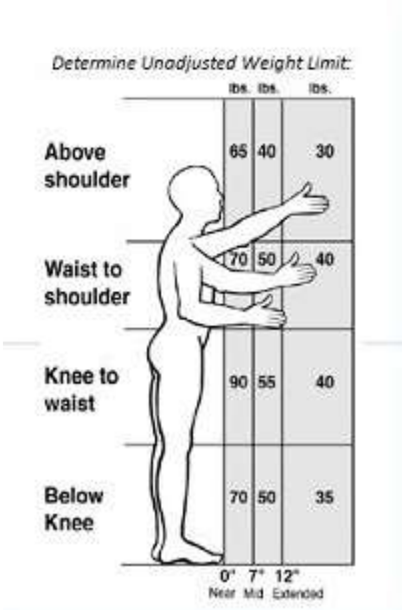


Figure 2.5: Unadjusted weight limits relative to body zones

Source: [23]

2.3.5. ISO 11228-1:2003 standard

ISO 11228-1:2003 specifies recommended limits for manual lifting and carrying while taking into account, respectively, the intensity, the frequency and the duration of the task. It applies to manual handling of objects with a mass of 3 kg or more and to moderate walking speed, i.e. 0.5 m/s to 1.0 m/sec on a horizontal level surface. does not include holding of objects (without walking), pushing or pulling of objects, lifting with one hand, manual handling while seated, and lifting by two or more people. ISO 11228-1:2003 is based on an 8 h working day. It does not concern analysis of combined tasks in a shift during a day [24], [25]. The manual lifting limits presented in ISO 11228-1:2003 are based upon the NIOSH 1991 Revised Lifting Equation [29], [30].

- **Anatomy and Biomechanics of Manual Lifting**

When an object is being lifted, the loading is transferred to the body in the form of compression and shear forces to the spinal column. So higher internal forces are required to accelerate the mass from rest when the load is lifted quickly. As more asymmetric (e.g. torso twisting) the posture, additional loads are placed on the spine [5], [31].

An external extension moment exists about the lumbar spine when a person leans forwards to lift an object. The heavier and more distant the object is from the body, the greater the external extension moment. To counteract the external extension moment and to perform the lift, the posterior torso muscles contract to create an internal moment about the spine, which comes with an opposed contraction of the anterior abdominal muscles, which further increases the loading on the spine[32], [5].

- **Back Injuries and Lifting**

The trunk can fail in three ways when a weight is lifted:

- ✓ Under excessive tension, the muscles and ligaments of the back can fail.
- ✓ Under excessive compression, the intervertebral disc may herniate as the nucleus is extruded.
- ✓ Excessive intra-abdominal pressure, the abdominal contents may be extruded through the abdominal cavity [5].

- **Work Related Musculoskeletal Disorders**

Institution of occupational safety and health UK (IOSH) defines Musculoskeletal disorders (MSDs) are conditions that affect the nerves, tendons, muscles and supporting structures, such as the discs in your back. They result from one or more of these tissues having to work harder than they're designed to [33**].**

- **Low Back and Shoulder Pain**

Musculoskeletal disorders of the back and shoulder are mainly caused from manual material handling tasks due to muscular fatigue. Depending of the severity, it can become an acute pain resulting in the individual staying away from work [5].

❖ Spinal Load when Lifting

Injury to the low back occurs when the spine tolerance is exceeded as a result of an interaction between dynamic spinal loads and tissue strains, which can be associated with the probability of high LBD risk. Many studies have shown that lifting task design (e.g. frequency and duration of the task, load weight, and location of the object to be lifted) is capable of damaging low back musculoskeletal tissues through biomechanical loads on the spine [19]. When lifting, muscles, facet joints, ligaments, and intervertebral discs of the spine, support and resist compression, torsion, and shear forces. These elevated forces occur as a result of a mechanical disadvantage within the muscles from the back which during a lift, result in higher loading on the spinal tissues, where the compression forces can be more than twenty times greater than the external load [34].

Following risk factors associated to reduce the tolerance limits of the tissues and to induce LBD and/or shoulder pain [5].

- ✓ Torso flexion
- ✓ Frequency or lift rate
- ✓ Duration of the lifting task
- ✓ External load moment (i.e., weight and distance from the body)
- ✓ Torso asymmetry (i.e., twisting).

❖ Torso Flexion

Numerous epidemiological and research studies have identified torso flexion to be associated with the increase in risk of LBD. During torso flexion, spinal stability is decreased as well as the extensor muscles ability to resist external loads Also the amount of shear forces over the intervertebral discs increases and the intervertebral discs have lower tolerances to compressive forces [35], thus increasing the risk of a LBD.

An increase in the strain on the posterior fibers of the annulus fibrous of the intervertebral discs occurs when repeated induced forward bending moments are performed close to the extreme flexion of the motion segment [36].

- **Frequency and Duration of the lifting task**

Several epidemiological studies have discovered that when a lifting task is performed at a repetitive pace, repetition could become a risk factor leading to Low back disorder [5]. According to [37] load weight and load frequency are closely linked with fatigue fractures of the vertebral bodies.

- **External Load Moment**

The external load moment results from the force transmitted at a certain distance from the musculoskeletal and osteoligamentous disc system, where most of the stress is induced to the low back .The load moment and spinal loading are directly proportional, as the external load moment increases, spinal loading increases as well [38].

- **Torso Twisting**

According to [39] found an increased risk of acute prolapsed lumbar intervertebral disc when twisting of the torso was performed while lifting objects. Also there is a higher risk of Low back disorder when the duration of task combined with asymmetry increases. Twisting motion increases in torso muscle co- contraction and spinal loading due to torso muscle co-activation. Moreover, muscle effort also increases gradually as twist increases [40], [5].

- **Gender and Anthropometry**

According to Several researchers gender makes a difference when different body masses are applied performing the same tasks [41], [42], [43], [5]. According to [44] a laboratory study conducted assessing the spine loading as a function of gender. They have tested 70 females and 70 males performing a controlled motion and free-dynamic whole body lifts. There were significant difference in spine loading between genders as a function of the anatomic differences in muscle co- contraction and differences in torso muscle sizes. Females demonstrated higher muscle co-contraction when lifting the same loads, and higher spinal loading. Furthermore, females have lower loading tolerance to the soft tissues such as the intervertebral discs, which likely places them at higher risk of injury.

2.4. Ergonomics Discomfort Scale

Ergonomic discomfort scale (Body part discomfort scale) is the most widely used subjective symptom survey tool that evaluates the respondent's direct experience of discomfort at different body parts. Human body is divided to body segments in ergonomics discomfort scale to evaluate respondent's discomfort in each body part.

3 STUDY 1: LIFTING INDEX STUDY

3.1. Introduction

According to the above literature review it is clear that several factors affects to the musculoskeletal disorders related to the manual lifting. Also it is revealed that there is a strong relationship between human body size and capability of handling load. So ability of handling same load without feeling any discomfort is changing according to the anthropometry. The anthropometry of human body is different to the several geographical regions. There were no ergonomic guideline developed considering Sri Lankan context and there were no researches conducted to validate the available manual material handling guide lines to Sri Lankan context.

Also according to the above literature review there are five widely used manual material lifting assessment tools used by ergonomists to analyze the lifting capability of humans. They are

- ✓ Revised 1991 National Institute for Occupational Safety and Health (NIOSH) Lifting Equation
- ✓ American Conference of Governmental Industrial Hygienists (ACGIH) lifting Threshold Limit Values
- ✓ Liberty Mutual Lifting Tables
- ✓ Washington State Ergonomics Rule Lifting Calculator
- ✓ ISO 11228-1:2003 standard-

Among the above five lifting assessment tools NIOSH lifting equation, ACGIH lifting threshold values, Washington State Ergonomics Rule Lifting Calculator and ISO 11228-1:2003 standard calculates the recommended or designed weight limit for each lifting tasks to perform the lifting activities with minimal ergonomic impact. But the Liberty Mutual Manual Materials Handling Tables provide both the male and female population percentages capable of performing manual material handling tasks without over exertion, rather than maximum acceptable weights and forces. The manual lifting limits presented in ISO 11228-1:2003 are based upon the NIOSH 1991 Revised Lifting Equation [29], [30]. Hence only the NIOSH lifting equation, ACGIH lifting threshold values and Washington State Ergonomics Rule Lifting

Calculator are used in this study to get comparative result to validate each of above lifting tools.

3.2. Methodology

Ergonomic discomfort scale is a simple tool even a person does not have a much knowledge on ergonomics can respond. So ergonomics discomfort scale is used in this study to evaluate and compare the lifting assessment tools. Human body is divided to 15 body segments in this study to evaluate respondent's discomfort in each body part. Body parts are divided according to the Figure 3.1 and Table 3.1.

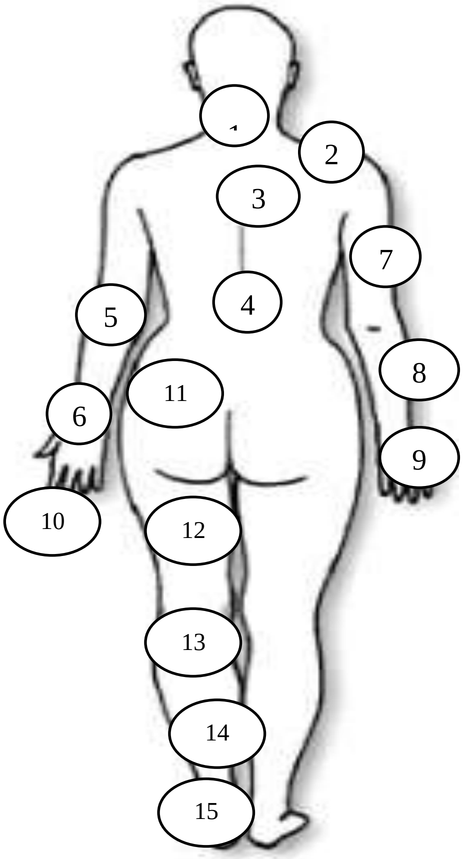


Figure 3.1: Body part for ergonomic discomfort

Table 3.1: Body part description for ergonomic discomfort scale

Body part No	**Body part**
1	Neck
2	Shoulder (R) / Shoulder (L)
3	Upper back
4	Lower back
5	Elbow (R) / Elbow (L)
6	Wrist (R) / Wrist (L)
7	Upper arm (R) / Upper arm (L)
8	Forearm (R) / Forearm (L)
9	Hand (R) / Hand (L)
10	Fingers(R) / Fingers(L)
11	Hips Or Buttock
12	Upper Leg (R) / Upper Leg (L)
13	Knee(R) / Knee(L)
14	Lower Leg (R) / Lower Leg (L)
15	Ankle/Foot(R) / Ankle/Foot(L)

The discomfort responses are recorded in a scale which is divided in to 6 scales from no discomfort to extreme discomfort as follows.

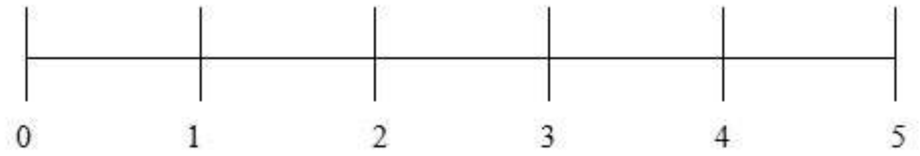


Figure 3.2: Ergonomic discomfort scale

The ergonomics discomfort responses are marked as follows.

0 – No discomfort

1- Minimal discomfort

2 – Mild discomfort

3 – Moderate discomfort

4 – Severe discomfort

5 – Extreme discomfort

A tire manufacturing plant selected for the conducting case study on validating the lifting assessment tools. The rubber tire manufacturing facility has 3 main operational plants manufacturing rubber rings for caster wheels, manufacturing complete caster wheels using rubber and plastics and manufacturing rubber solid tires. About 250 workers involved in production activities, raw material storage and finished goods stores participated in this case study.

Ergonomics discomfort scale form distributed among all the above employees at the beginning of each shift to mark the discomfort value at the beginning and end of the shift. See Appendix: 6 for sample ergonomics discomfort sheet. Then jobs were sorted, which handle more than 10 kg per lift, lifting frequency 8 to 12 lifts per hour and 8 hours working duration per day. There were 12 jobs found in this category and then low back discomfort value differences were calculated between end and beginning of the work for those selected jobs.

Discomfort value of the job = Discomfort value at beginning of the shift - Discomfort value at end of the shift

Then the average discomfort value for low back discomfort calculated for all the selected jobs. Also the output of all the lifting assessment tools calculated and converted to a lifting index similar to the lifting indexes calculated in NIOSH lifting equation using following formats in Figures 3.3, 3.4 and 3.5.

ACGIH Lifting Threshold Limit Values calculator -Job Analysis Sheet

Job No	

ACGIH Lifting Variable	Value
Weight (kg)	
Lifting frequency (lifts per hour)	
Vertical Zone (cm)	
Horizontal zone (cm)	
Lifting TLV (kg)	
Lifting index	
Status	

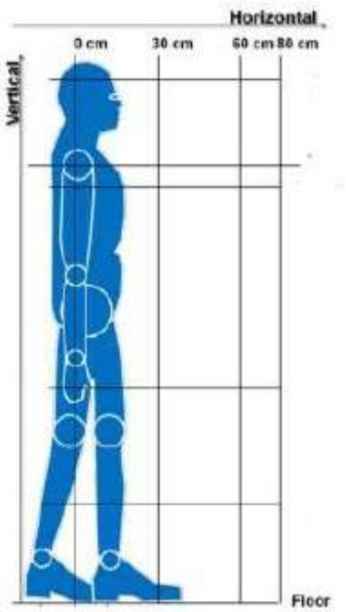
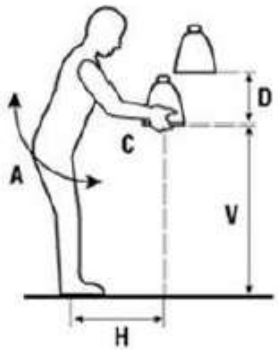


Figure 3.3: ACGIH lifting threshold limit values - Job analysis sheet

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	



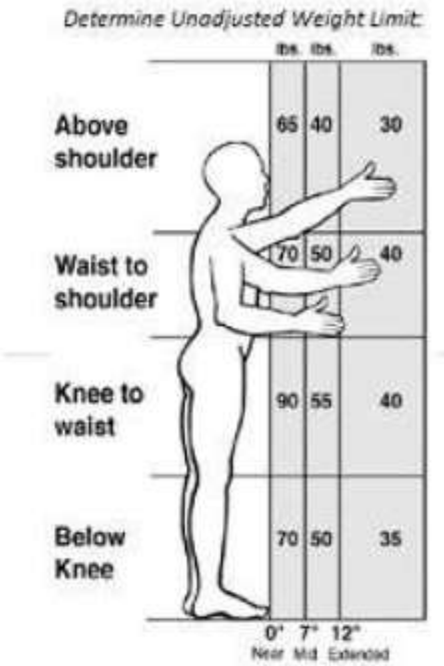
NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**) cm		
Vertical Location (**V**) cm		
Travel Distance (**D**) cm		
Angle of Asymmetry (**A**) Degrees		
Coupling (**C**)(1 -good, 2- fair, 3 - poor)		
Frequency - (**F**) Lifts/hour		
Load lifted (**L**) kg		
Duration (**D**) (**1**-short, 2- Moderate, 8 - long)		
RWL = 23 xHM x VM x DM x AM x FM x CM		
Lifting index		
Status		

Figure 3.4: NIOSH lifting equation: Job analysis sheet

WISHA Lifting Calculator -Job Analysis Sheet

Job No	

Actual weight (kg)	
Unadjusted Weight Limit (lb)	
Unadjusted Weight Limit (kg)	
Lifts per Minute	
Hours per Day	
Twisting	
Horizontal distance (cm)	
Vertical distance (cm)	



Unadjusted weight Limit (kg) x	
Twisting Adjustment	
Adjusted Weight Limit (kg) x	
Limit Reduction Multiplier	
Weight Limit (kg)	

Actual Weight(kg)/	
Weight Limit(kg)	
Lifting Index	
Status	

Figure 3.5: WISHA lifting calculator: Job analysis sheet

3.3. Results and discussion

The lifting indexes calculated for all the 12 jobs considering the three assessment tools. See Appendix: 7 to Appendix: 42 for calculation details. The summary of all the jobs are presented in Table 3.2.

Table 3.2: Lifting index summary of jobs

Job No	Horizontal distance (H) inches	Vertical distance (V) inches	Lifting distance (D) inches	Frequency lifts/hr	Weight (kg)	ACGIH Lifting Index	NIOSH Lifting Index	WISHA Lifting Index
1	10	15	9	12	25	1.39	1.43	1.29
2	20	13	7	12	12.5	0.89	1.48	0.92
3	10	40	34	10	25	0.78	1.74	1.17
4	18	36	30	10	10	0.71	1.17	0.65
5	10	50	44	10	25	0.78	1.84	1.30
6	14	45	39	10	20	1.25	1.39	1.30
7	10	16	8	12	15	0.83	0.85	0.78
8	14	30	22	12	12.5	0.89	1.15	0.81
9	18	15	9	12	15	1.07	1.48	1.10
10	8	48	42	11	25	0.78	1.80	1.10
11	17	48	42	10	12.5	0.78	1.53	0.69
12	16	46	40	9	10	0.62	1.13	0.55

The average low back discomfort level for each job calculated. See Table 3.3 for the summary of average low back discomfort level difference in each job.

Table 3.3: Average low back disorder

Job	No of ergonomic discomfort feedbacks	Average low back discomfort level at start of job	Average low back discomfort level difference
1	723	0.16	2.58
2	217	0.05	2.36
3	946	0.15	2.55
4	1211	0.11	1.41
5	687	0.07	2.43
6	413	0.20	2.63
7	227	0.06	0.91
8	1485	0.18	2.38
9	784	0.08	2.28
10	843	0.10	2.31
11	214	0.11	1.32
12	238	0.04	1.27

The average low back discomfort level results and lifting index values for each job related to all three lifting assessment tools compared to check the validity of the lifting assessment tools to each job. The results were as Figure 3.6.

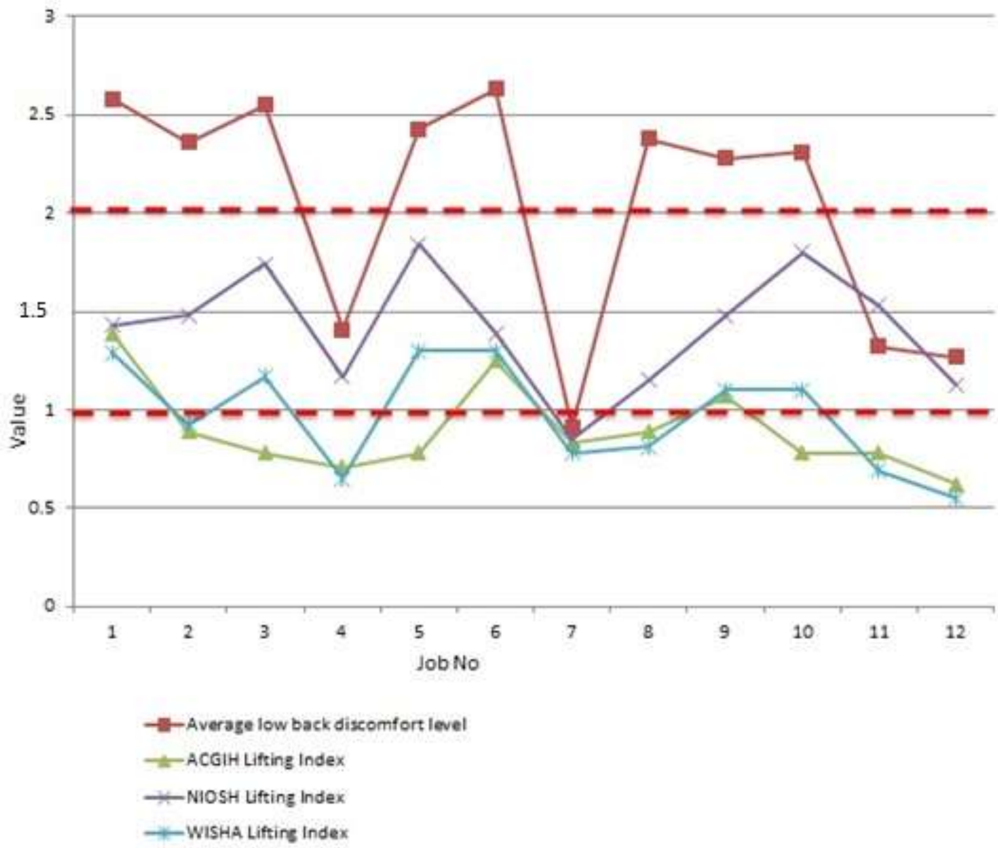


Figure 3.6: Average low back discomfort level and lifting indexes of jobs

By analyzing the above case study it is proven that there is a relationship between lifting indexes and average low back discomfort value. Only the male population were considered during the above study and data collected from about 250 workers more than 3 months and then average low back discomfort levels were calculated. The height, weight and age data values of the all the participants collected. See Appendix 63. The average height of the participant was 1643 mm and standard deviation is 71.5 mm in selected population. According to [45] average height of Sri Lankan male is 1639 mm and standard deviation is 63.5 mm. See Appendix 64 to refer the body sizes of Sri Lankan population. Therefore this population can be used as a sample to represent the Sri Lankan population.

4 MANUAL LIFTING GUIDELINE FOR SRI LANKAN POPULATION

4.1. Introduction

There are several international health and safety standards used in Sri Lanka such as ISO OHSAS 18001: 2007, ILO OSH guidelines but there is no proper ergonomic guideline developed for manual material handling considering the Sri Lankan context. There are large number of ergonomic guidelines and ergonomic tools developed and practiced by ergonomists in the developed countries, but it is hard find ergonomics researches related to Sri Lankan context. Three of the major lifting assessment tools practiced by the international ergonomists were analyzed using a case study and developed a manual lifting guide line for Sri Lankan context using the results of the above case study.

4.2. Methodology

The results of the lifting index case study used for the development of the ergonomics guideline for manual lifting for Sri Lankan population. In this study the jobs which have average low back discomfort level higher than 2 considered as risky jobs and jobs which have average discomfort level less than 2 considered as safe jobs. Also jobs which have lifting index higher than 1 considered as risky jobs and jobs which have lifting index less than 1 considered as safe jobs. The lifting positions categorized according to 6 zones considering the vertical and horizontal distance to the object being lifted from the body of worker. See Figure 4.1.

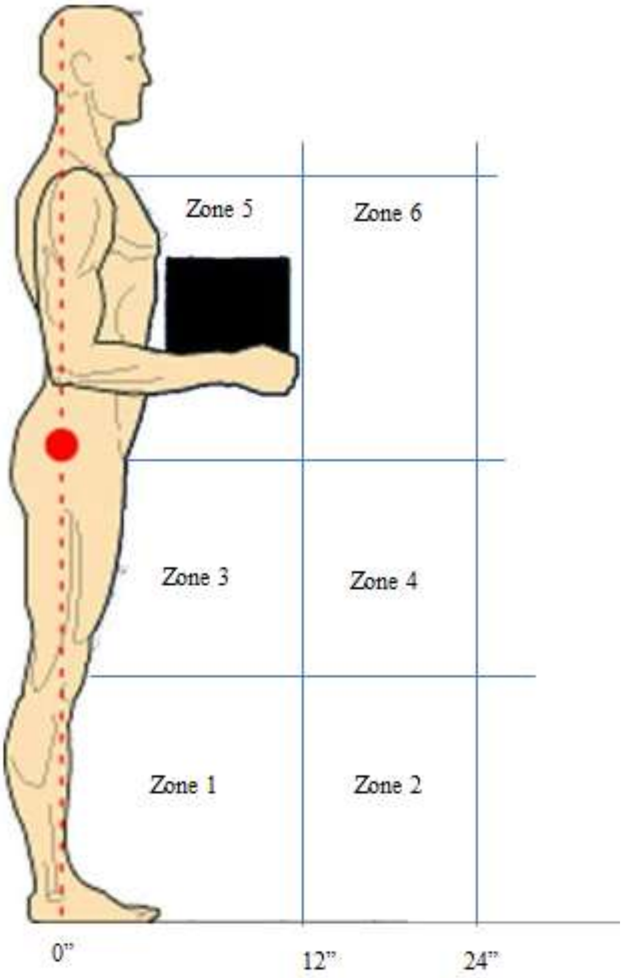


Figure 4.1: Manual lifting zones

The validity of each tool to the each zone identified using following figures. If the lifting index value of lifting assessment tool is less than 1 and the average discomfort value for the job exceeded value 2 then that lifting assessment tool considered as not valid for that job and also for the related lifting zone.

	Risky jobs
	Safe jobs
	Lifting index result validated from Average discomfort result
	Lifting index result not validated from Average discomfort result

Figure 4.2: Colour codes for identifying the validity status of jobs

Zone 1

Job1

	ACGIH	NIOSH	WISHA
Lifting Index	1.39	1.43	1.29
LB Discomfort	2.58		
Result			

Figure 4.3: Validity of lifting assessment tools – Job 1

Job 7

	ACGIH	NIOSH	WISHA
Lifting Index	0.83	0.85	0.78
LB Discomfort	0.91		
Result			

Figure 4.4: Validity of lifting assessment tools – Job 7

Zone 2

Job2

	ACGIH	NIOSH	WISHA
Lifting Index	0.89	1.48	0.925
LB Discomfort	2.36		
Result			

Figure 4.5: Validity of lifting assessment tools – Job 2

Job 9

	ACGIH	NIOSH	WISHA
Lifting Index	1.07	1.48	1.1
LB Discomfort	2.28		
Result			

Figure 4.6: Validity of lifting assessment tools – Job 9

Zone 3

Job 3

	ACGIH	NIOSH	WISHA
Lifting Index	0.78	1.74	1.17
LB Discomfort	2.55		
Result			

Figure 4.7: Validity of lifting assessment tools – Job 3

Zone 4

Job 4

	ACGIH	NIOSH	WISHA
Lifting Index	0.71	1.17	0.65
LB Discomfort	1.41		
Result			

Figure 4.8: Validity of lifting assessment tools – Job 4

Job 8

	ACGIH	NIOSH	WISHA
Lifting Index	0.89	1.15	0.81
LB Discomfort	2.38		
Result			

Figure 4.9: Validity of lifting assessment tools – Job 8

Zone 5

Job 5

	ACGIH	NIOSH	WISHA
Lifting Index	0.78	1.84	1.3
LB Discomfort	2.43		
Result			

Figure 4.10: Validity of lifting assessment tools – Job 5

Job 10

	ACGIH	NIOSH	WISHA
Lifting Index	0.78	1.8	1.1
LB Discomfort	2.31		
Result			

Figure 4.11: Validity of lifting assessment tools – Job 10

Zone 6

Job 6

	ACGIH	NIOSH	WISHA
Lifting Index	1.25	1.39	1.3
LB Discomfort	2.63		
Result			

Figure 4.12: Validity of lifting assessment tools – Job 6

Job 11

	ACGIH	NIOSH	WISHA
Lifting Index	0.78	1.53	0.69
LB Discomfort	2.32		
Result			

Figure 4.13: Validity of lifting assessment tools – Job 11

Job 12

	ACGIH	NIOSH	WISHA
Lifting Index	0.62	1.13	0.55
LB Discomfort	1.27		
Result			

Figure 4.14: Validity of lifting assessment tools – Job 12

4.3. Proposed lifting guideline for Sri Lankan population

The results of the case study show that all three lifting tools used for the case study not valid for some of the jobs in selected population. Therefore above results imply that all three lifting tools used for the case study not also valid for some lifting zones for the Sri Lankan population.

According to the above case study NIOSH lifting equation can be used for all the manual lifting applications from foot level to shoulder level and 24 inches horizontal distance away from body. WISHA Ergonomics Rule Lifting Calculator was valid for all the lifting activities up to the shoulder level in vertical distance and up to the 12 inches away from body in horizontal distance. The results of case study shows that the weight limits calculated from WISHA Rule Lifting Calculator may cause for low back discomfort for the worker and the average discomfort value is greater than 2 when horizontal lifting position exceeds 12 inches. Therefore WISHA Rule Lifting Calculator cannot be used for lifting activities which 12 inches horizontally away from human body. The ACGIH threshold limit value is valid only for the lifting activities which handle only up to the knee level in vertical distance and horizontally up to 12 inches away from the body.

The result of the above study is suggested as a guideline for manual lifting for Sri Lankan population. See Table 4.1 and Figure 4.15 for proposed guideline for Sri Lankan population. This guideline is developed for only the lifting activities up to the 150 cm in vertical distance and up to 50 cm in horizontal distance because it is the normal working range in manual lifting activities. The vertical heights of the lifting zones were defined for the closest 10^{th} centimeter value of knee height, hip height and shoulder height of 95^{th} percentile Sri Lankan male population according to anthropometric data in [45].

Table 4.1: Proposed guideline for using lifting tools for Sri Lankan population

Zone	Lifting assessment tool		
	ACGIH	**NIOSH**	**WISHA**
Zone 1	Valid	Valid	Valid
Zone 2	Not Valid	Valid	Not Valid
Zone 3	Not Valid	Valid	Valid
Zone 4	Not Valid	Valid	Not Valid
Zone 5	Not Valid	Valid	Valid
Zone 6	Not Valid	Valid	Not Valid

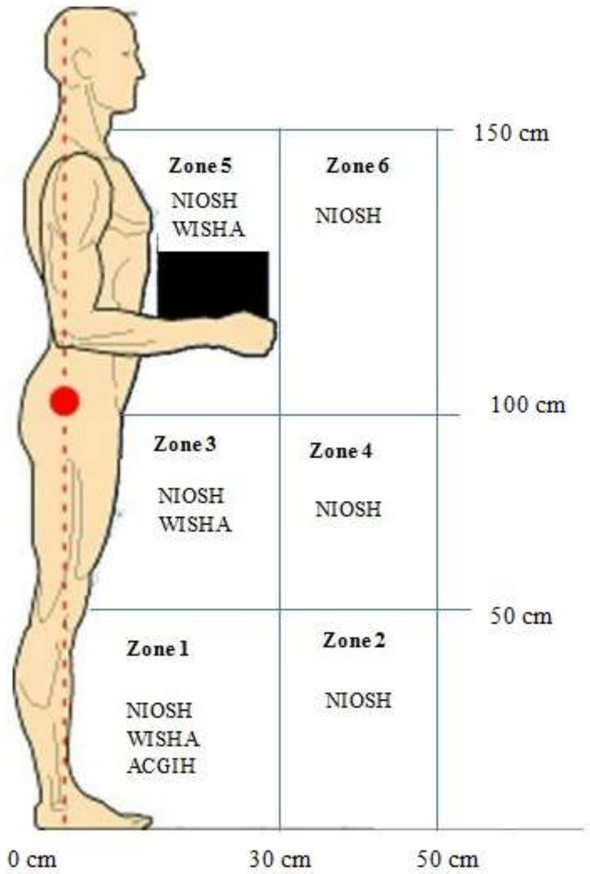


Figure 4.15: Proposed guideline for using lifting tools for Sri Lankan population

5 VALIDATION OF THE PROPOSED GUIDE LINE

5.1. Introduction

The manual lifting guideline was developed using the results of case study conducted with normal routine jobs in a manufacturing plant. Those jobs were normally in random areas of each manual lifting zone related to the human body. Therefore the validity of the above guideline was checked for the minimum and maximum ends of each zone.

5.2. Methodology

A new case study conducted for validating the proposed guideline with using the same manufacturing plant. 120 employees participated daily for the case study and the no of employees varied from 108 to 120 due to absenteeism. The case study conducted for the 6 zones. Height adjustable tables were used for adjusting the vertical distance. A plastic crate used as the lifting weight and the weight of the object controlled by filling plastic castor wheels to the plastic crate. The crate has 2 handles in both sides and height to the bottom of the crate to the handle is 25 cm. The center of the handle lies 20 cm in horizontal direction. Therefore the case study carried out only for 20 cm to 50 cm distance in horizontal direction and 25 cm inches to 150 cm distance in vertical direction as shown in Figure 5.1.

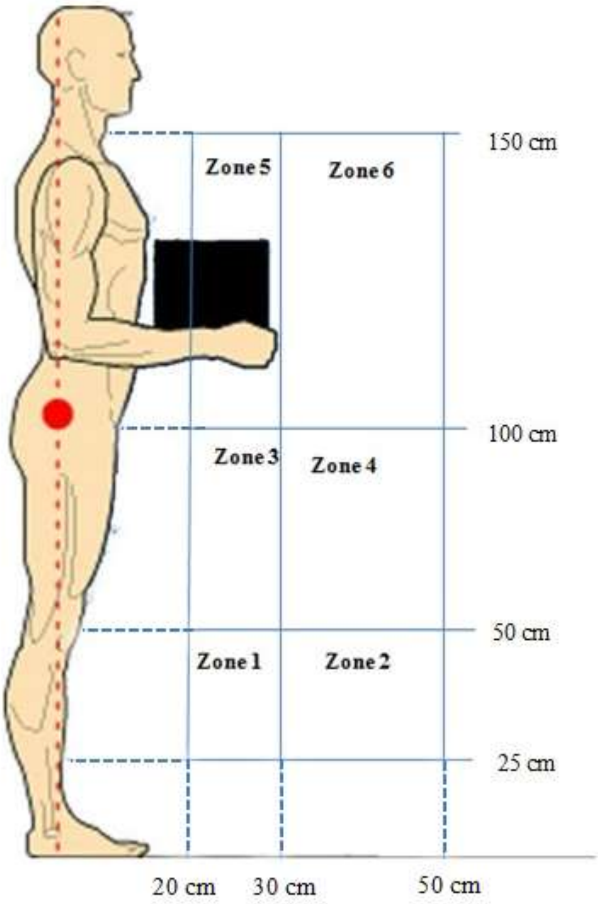


Figure 5.1: Manual lifting zones used for the case study

Recommended weight calculated for maximum and minimum horizontal distances in each zone and all the lifting tasks started from the minimum vertical distance in each zone and ended in maximum vertical distance in same zone. The summary of the lifting distances are shown in Table 5.1 and Table 5.2.

Table 5.1: Distance figures for minimum horizontal distance in each zone

Zone	**Horizontal distance (cm)**	**End of vertical lift (cm)**	**Lifting distance (cm)**
Zone1	20	50	30
Zone2	30	50	30
Zone3	20	100	50
Zone4	30	100	50
Zone5	20	150	50
Zone6	30	150	50

Table 5.2: Distance figures for maximum horizontal distance in each zone

Zone	**Horizontal distance (cm)**	**End of vertical lift (cm)**	**Lifting distance (cm)**
Zone1	30	50	30
Zone2	50	50	30
Zone3	30	100	50
Zone4	50	100	50
Zone5	30	150	50
Zone6	50	150	50

Then the recommended maximum weight limit calculated using the three lifting assessment tools for the valid zones in above 12 cases and selected the maximum weight from the three lifting tools for each case. Refer Appendix: 43 to Appendix: 62 for weight limit calculation for each case and see Table 5.3 for the summary of the study.

Table 5.3: Maximum weight limit calculation for the jobs in case study

Job	Horizontal distance (cm)	End of vertical lift (cm)	Lifting distance (cm)	Calculated weight limits (kg)			Maximum weight limit (kg)
				NIOSH	WISHA	ACGIH	
Job A	20	50	30	18.1	19.3	18	19.3
Job B	30	50	30	15.1	N/A	N/A	15.1
Job C	20	100	50	16.5	21.2	N/A	21.2
Job D	30	100	50	13.7	N/A	N/A	13.7
Job E	20	150	50	13.8	19.3	N/A	19.3
Job F	30	150	50	11.5	N/A	N/A	11.5
Job G	30	50	30	15.1	19.3	18	19.3
Job H	50	50	30	9.0	N/A	N/A	9.0
Job I	30	100	50	13.7	21.2	N/A	21.2
Job J	50	100	50	8.2	N/A	N/A	8.2
Job K	30	150	50	11.5	19.3	N/A	19.3
Job L	50	150	50	6.9	N/A	N/A	6.9

The Caster wheels lifting tasks of the manufacturing plant were designed according to the distance limits and maximum weight limits calculated from the Table 5.3. Ergonomic discomfort form distributed to mark the low back discomfort at the beginning and at the end of each 8 hour job. All the lifting tasks were designed for 12 lifts per hour frequency. Then calculated the low back discomfort difference of each operator and calculated the average low back discomfort for each job.

5.3. Results and discussion

The calculated average low back discomfort difference results in above case study is summarized in Table 5.4 and Figure 5.3.

Table 5.4: Average low back discomfort values of validation case study

Job No	No of participants to the analysis	Average low back disorder value at start of the job	Average low back discomfort value difference
Job A	115	0.06	1.13
Job B	119	0.09	1.23
Job C	111	0.04	1.28
Job D	108	0.07	1.32
Job E	113	0.11	1.17
Job F	118	0.07	1.48
Job G	112	0.12	1.63
Job H	144	0.17	1.31
Job I	155	0.08	1.51
Job J	169	0.03	1.41
Job K	171	0.05	1.49
Job L	126	0.02	1.08

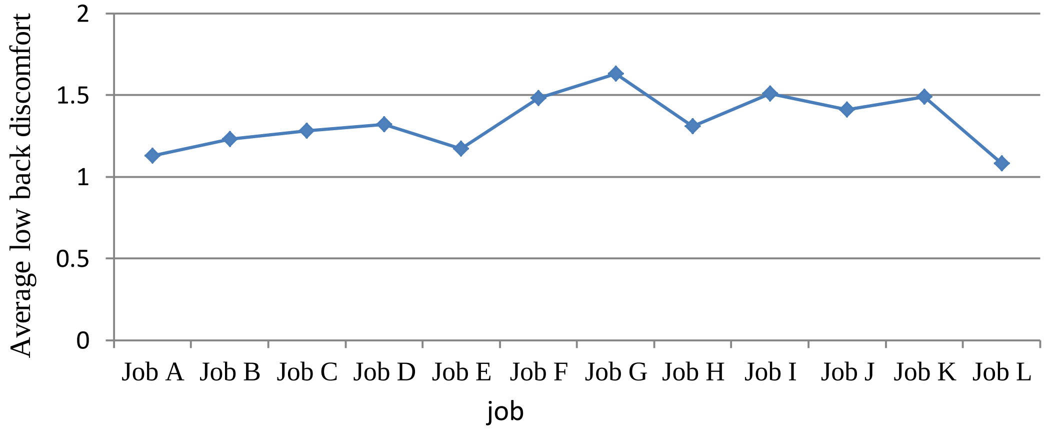


Figure 5.2: Average low back discomfort result of the validation case study

The results indicate that all the average low back disorder values related to the jobs designed using maximum weight and distance limits of the developed guidelines for Sri Lankan population were less than 2. Therefore it is proven that the developed guideline is valid for selected sample.

The available lifting assessment tools developed based on imperial units but the zones for the Sri Lankan guideline was defined using metric units because metric units are the common measuring unit in Sri Lankan context.

The average height of the sample population for validation case study is 1642 mm and standard deviation is 70mm. See appendix 65 for height, weight and age values of sample population. According to [41] average height of Sri Lankan male is 1639 mm and standard deviation is 63.5 mm. The average value and standard deviation is very close to the related values of Sri Lankan population. Therefore the result of the above study is valid for the Sri Lankan population.

6 DISCUSSION

6.1. Introduction

The major objective of this research is to develop an ergonomics guideline for manual material lifting for the Sri Lankan population. Revised National Institute for Occupational Safety and Health Lifting Equation, American Conference of Governmental Industrial Hygienists lifting Threshold Limit Values and Washington Industrial Safety and Health Act Rule Lifting Calculator were identified as key lifting assessment tools in the industry. A case study was conducted in a manufacturing plant to check the validity of the above manual lifting assessment tools identified through the literature review. Ergonomic discomfort scale was used as a tool for getting the workers response on above tools. The outputs of all the lifting assessment tools calculated and converted to lifting indexes similar to the lifting index calculated in NIOSH lifting equation. Results of the lifting assessment tools compared with the ergonomic discomfort feedback of the workers who performing lifting tasks. The ergonomic guideline for Sri Lankan population was developed by using the results of above comparison. The developed guideline was validated using a case study.

The results of the two case studies show that there is a strong relationship between lifting load and low back discomfort value. Al-Otaibi in [46] and Chaffin in [47] also present in their research that there is a correlation between manual lifting tasks and low back pain. According to USA national center for health and statistic [48] average height of a USA male population is 173.25 cm (69.3 inches) and according to [45] average height of Sri Lankan male is 163.9 cm. The average height of the sample population in case study 1 is 164.3 cm and sample population in case study 2 is 164.2 cm. Therefore the both samples can be used as sample Sri Lankan population. The above three lifting assessment tools are practiced in USA for a long period of time and they are validated for USA population. The result of the research shows that all the above three tools are not valid for all lifting tasks and they are valid only for some of the lifting zones. Ford in [6] discusses that lifting capability of human depend on the body height of the person. Therefore the result of the research is compatible with finding in [6] because there is a considerable difference in body height of Sri Lankan and USA population.

According to the research finding NIOSH lifting equation is valid for all manual lifting jobs in all lifting regions because it always identifies high risk jobs and gives a safe recommended weight limit. Also in [19] Marras presents that NIOSH correctly identify 73% of the high risk jobs. According to the findings of the research NIOSH lifting equation valid for all the lifting zones and WISHA ergonomics rule lifting calculator valid only for the jobs up to 30 cm horizontally away from body. Therefore NIOSH and WISHA lifting assessment tools valid for lifting jobs performing closer to the body and also Russel in [7] presents that WISHA and NIOSH have approximately equivalent results for stressful near reach lifts.

6.2. Limitations of the study

Ergonomic discomfort scale was used for this study to evaluate the probability of musculoskeletal disorder due to manual lifting task in each job. Ergonomic discomfort scale is a qualitative tool and discomfort feeling may vary from person to person and therefore it may affect to the results of the study. The effect of personal feeling to validity of the study was reduced by conducting the validation case study with using the same participants to the all 12 selected jobs. Therefore the impact from the qualitative nature was reduced in the comparative study.

The posture of the lifting may varying from worker to worker and training was given for all the operators on correct material lifting postures to reduce the impact due to postural variations. The manufacturing plant has about 10 female workers but they are used to perform jobs with minimum lifting tasks. Therefore the study was conducted to check the validity only for the male population. A plastic crate filled with plastic complete wheels was used as the lifting weight of the validation case study. The handle height of the crate is about 25 cm and horizontal distance to the center of the handle is 20 cm. Therefore the Sri Lankan guideline validated only for the lifting tasks started 20 cm horizontally and 25 cm vertically away from the body of the human body.

There were no regular manual lifting jobs in the selected manufacturing plant associated with twisting of the body. Therefore the guideline was developed only for the lifting jobs with zero degrees of twisting. The frequency of most of the lifting jobs performing for 8 hours is less than or equal to 12 in the plant due to the productivity limitations. Therefore the Sri Lankan guideline was developed for the lifting jobs which have frequency less than or equal 12 lifts per hour.

The development of the manual lifting guideline was limited only for 2- handed tasks due to the limitations of the existing lifting assessment tools. Also impacts from the environmental parameters such as temperature and humidity to the lifting tasks were neglected during this study. Only the short term discomforts were considered for this research. The ergonomic discomfort sheet was filled at the end of the shift and the pains appear after certain period such as next day and also long term effects were not considered during this study.

6.3. Future research opportunities

Ergonomic discomfort scale was used in this study for assessing the validity of the manual lifting assessment tools. The findings of the research may further validated by ergonomics assessment tools such as Rapid Entire Body Assessment tool (REBA) and Rapid Upper Limb Assessment (RULA) tool to minimize the postural impact to the validity of the study. The Sri Lankan guideline was developed only for the male population and therefore there is an opportunity to develop an ergonomic guideline valid for female population.

The research was conducted only for the lifting tasks with duration of 8 hours. Some of the Sri Lankan industrial organizations use extended work durations such as 12 hours shifts. Therefore it may be helpful for the industry if there is any guideline for extended working durations. Also the lifting capability may increase when considering the lower working durations. Hence there is an opportunity to conduct a research to check the validity of the lifting assessment tools for shorter durations. Also there is an opportunity develop an ergonomic guideline for lifting tasks associated with high lifting frequencies.

7 CONCLUSIONS

The conclusions of this research listed according to the objectives of the research. Revised 1991 National Institute for Occupational Safety and Health (NIOSH) Lifting Equation, American Conference of Governmental Industrial Hygienists (ACGIH) lifting Threshold Limit Values, Liberty Mutual Lifting Tables, Washington Industrial Safety and Health Act (WISHA) Rule Lifting Calculator and ISO 11228-1:2003 standard are the five major manual lifting assessment tools widely practiced by the ergonomists in the world to minimize the health and safety risks associated with manual lifting tasks.

ACGIH lifting threshold limit values, revised NIOSH lifting equation (1991) and WISHA ergonomic rule lifting calculator were used for the research to check the validity of the lifting assessment tools to the Sri Lankan context. The results of case study related to tire manufacturing facility shows that all three lifting tools used for the case study were not valid for some of the jobs in selected population. Therefore above results indicates that all three lifting tools used for the case study not also valid for some lifting regions in the manual lifting tasks in the Sri Lankan population. Also the results of the lifting index values and average ergonomic discomfort values shows there is a strong relationship between low back discomfort and lifting weights.

According to the developed manual lifting guideline for Sri Lanka, NIOSH lifting equation can be used for all the manual lifting applications from foot level to 150 cm vertical height and 50 cm horizontal distance away from body. WISHA Ergonomics Rule Lifting Calculator is valid for all the lifting activities up to 150cm in vertical height and up to 30 cm away from body in horizontal distance. The ACGIH threshold limit value calculator can be used only for the lifting activities which handle only up to 50 cm in vertical height and horizontally up to 30cm away from the body.

The results of the validation case study shows that the average low back discomfort level has reduced to values less than two (minimal discomfort) in all jobs. Therefore the developed guideline valid for the selected population and hence it is valid for the Sri Lankan population. The developed guideline was validated only for male population and future development of manual lifting guideline for Sri Lankan female population is possible.

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APPENDICES

Appendix 1: NIOSH frequency multiplier table

Frequency Multiplier Table (FM)

Source: [49]

Frequency Lifts/min (F):	Work Duration: <= 1 Hour		>1 but <=2 Hours		>2 but <=8 Hours	
	V<30+	V>=30	V<30	V>=30	V<30	V>=30
<=0.2	1.00	1.00	.95	.95	.85	.85
0.5	.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.13
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.34	.00	.00	.00	.00
14	.00	.31	.00	.00	.00	.00
15	.00	.28	.00	.00	.00	.00
>15	.00	.00	.00	.00	.00	.00

\+ Values of V are in inches

: For lifting less frequently than once per 5 minutes, set F = 0.2 lifts/minute

Appendix 2: Table to select the adequate ACGIH lifting TLV table

TABLE TO SELECT THE ADEQUATE ACGIH LIFTING TLV TABLE

Lifts per hour	**Duration of Task per day**	
	≤ 2h	**>2h**
≤ 60	Table 3	
≤ 12		Table 3
> 12 and ≤ 30		Table 4
> 60 and ≤ 360	Table 4	
> 30 and ≤ 360		Table 5

Source: [5]

Appendix 3: ACGIH Lifting table 1- TLVs for infrequent lifting

TLVs® for Infrequent Lifting:

≤ 2 Hours per Day with ≤ 60 Lifts per Hour OR

≥ 2 Hours per Day with ≤ 12 Lifts per Hour

	Horizontal Zone		
	Close: < 30 cm	**Intermediate:3 0 to 60 cm**	**Extended: > 60 to 80 cm**
Reach limit or 30 cm above shoulder to 8 cm below shoulder height	16 kg	7 kg	**No known safe limit for repetitive lifting**
Knuckle height to Below shoulder	32 kg	16 kg	9 kg
Middle shin to knuckle height	18 kg	14 kg	7 kg
Floor to middle shin height	14 kg	**No known safe limit for repetitive lifting**	**No known safe limit for repetitive lifting**

Source: [5]

Appendix 4: ACGIH Lifting table 2 - TLVs for moderately frequent lifting

> 2 Hours per Day with > 12 and ≤ 30 Lifts per Hour OR

≤ 2 Hours per Day with > 60 and ≤ 360 Lifts per Hour

	Horizontal Zone		
Vertical Zone	**Close:** **< 30 cm**	**Intermediate:** **30 to 60 cm**	**Extended:** **> 60 to 80 cm**
Reach limit or 30 cm above shoulder to 8 cm below shoulder height	14 kg	5 kg	**No known safe limit for repetitive lifting**
Knuckle height to Below shoulder	27 kg	14 kg	7 kg
Middle shin to knuckle height	16 kg	11 kg	5 kg
Floor to middle shin height	9 kg	**No known safe limit for repetitive lifting**	**No known safe limit for repetitive lifting**

Source [5]

Appendix 5: ACGIH Lifting table 3 - TLVs for frequent, long duration lifting

TLVs for frequent, long duration lifting

> 2 Hours per Day with > 30 and ≤ 360 Lifts per Hour

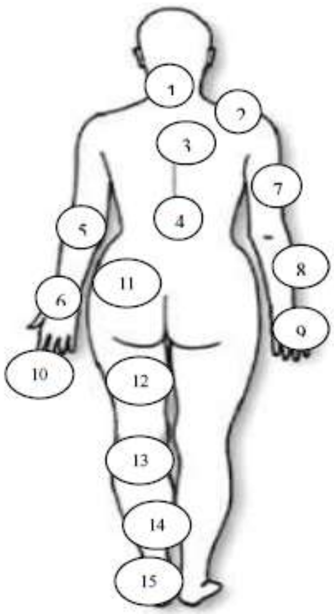
Vertical Zone	**Horizontal Zone** **Close:** **< 30 cm**	 **Intermediate:3** **0 to 60 cm**	 **Extended:** **> 60 to 80 cm**
Reach limit or 30 cm above shoulder to 8 cm below shoulder height	11 kg	**No known safe limit for repetitive lifting**	**No known safe limit for repetitive lifting**
Knuckle height to Below shoulder	14 kg	9 kg	5 kg
Middle shin to knuckle height	9 kg	7 kg	2 kg
Floor to middle shin height	**No known safe limit for repetitive lifting**	**No known safe limit for repetitive lifting**	**No known safe limit for repetitive lifting**

Source: [5]

Appendix 6: Ergonomic discomfort scale

Ergonomic discomfort scale

Date :
Shift :
Emp No :
Job :
Job No
Start time:
End time:

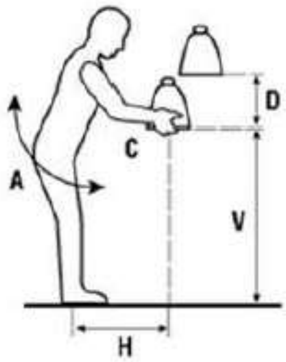


Body Part		No discomfort					Extreme discomfort
1	Neck	0	1	2	3	4	5
2	Shoulder (R)	0	1	2	3	4	5
	Shoulder (L)	0	1	2	3	4	5
3	Upper back	0	1	2	3	4	5
4	Lower back	0	1	2	3	4	5
5	Elbow (R)	0	1	2	3	4	5
	Elbow (L)	0	1	2	3	4	5
6	Wrist (R)	0	1	2	3	4	5
	Wrist (L)	0	1	2	3	4	5
7	Upper arm (R)	0	1	2	3	4	5
	Upper arm (L)	0	1	2	3	4	5
8	Forearm (R)	0	1	2	3	4	5
	Forearm (L)	0	1	2	3	4	5
9	Hand (R)	0	1	2	3	4	5
	Hand (L)	0	1	2	3	4	5
10	Fingers(R)	0	1	2	3	4	5
	Fingers(L)	0	1	2	3	4	5
11	Hips Or Buttock	0	1	2	3	4	5
12	Upper Leg (R)	0	1	2	3	4	5
	Upper Leg (L)	0	1	2	3	4	5
13	Knee(R)	0	1	2	3	4	5
	Knee(L)	0	1	2	3	4	5
14	Lower Leg (R)	0	1	2	3	4	5
	Lower Leg (L)	0	1	2	3	4	5
15	Ankle/Foot(R)	0	1	2	3	4	5
	Ankle/Foot(L)	0	1	2	3	4	5

Appendix 7: NIOSH Lifting Equation calculator -Job Analysis Sheet for job 1

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	1



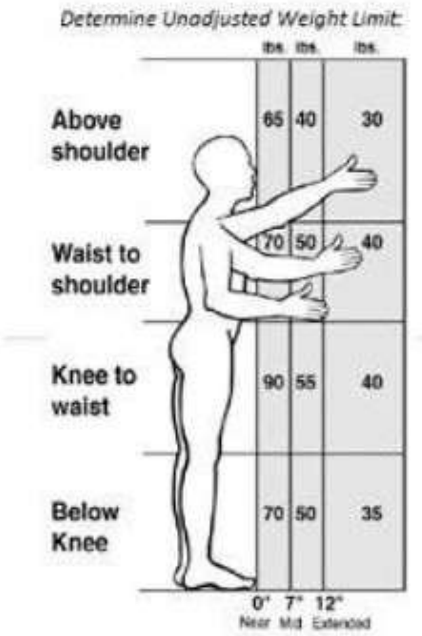
NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**)	10in	1
Vertical Location (**V**)	15in	.89
Travel Distance (**D**)	9in	1
Angle of Assymetry (**A**)	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	Fair	1
Frequency - (**F**)	12/hr	.85
Average load lifted (**L**) (lbs)		25kg
Max Load Lifted (**L**) (lbs)		25kg
Duration (**D**) (**1**-short, 2- Moderate, 8 - long)	8 hrs	1
RWL = 23 xHM x VM x DM x AM x FM x CM		17.4 kg
Lifting index		1.43
Status		Risky

Appendix 8: WISHA Lifting Calculator -Job Analysis Sheet for job1

WISHA Lifting Calculator -Job Analysis Sheet

Job No	1

Actual weight	25 kg
Unadjustted Weight Limit	50lb
Lifts per Minute	0.2
Hours per Day	8
Twisting	0



Unadjusted weight Limit x	50lb
Twisting Adjustment	1
Adjusted Weight Limit x	50lb
Limit Reduction Multiplier	.85
Weight Limit	42.5lb(19.3kg)

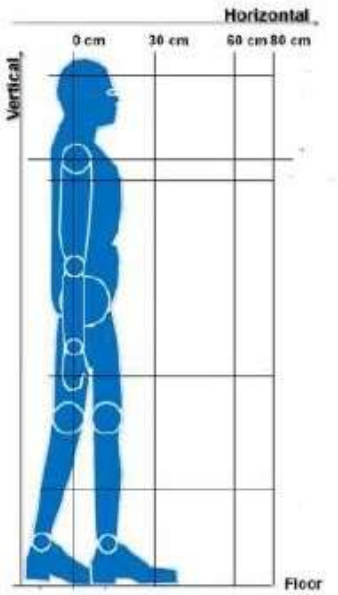
Weight Limit	19.3
Actual Weight	25
Lifting Index	1.29
Status	Risky

Appendix 9: ACGIH Lifting TLV calculator -Job Analysis Sheet for job 1

ACGIH Lifting Threshold Limit Values calculator -Job Analysis Sheet

Job No | 1

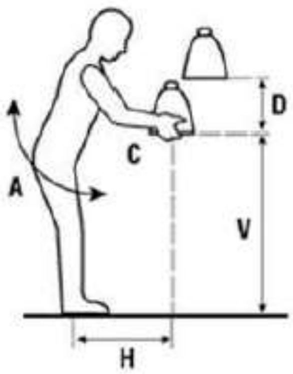
ACGIH Lifting Variable	Value
Weight	25kg
Lifting frequency	12 lift/hr
Vertical Zone	15 inches
Horizontal zone	10 inches
Lifting TLV	18 kg
Lifting index	1.39
Status	Risky



Appendix 10: NIOSH Lifting Equation calculator -Job Analysis Sheet for job 2

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	2



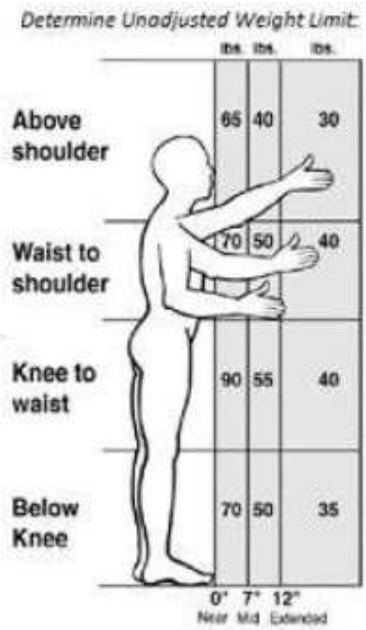
NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**)	20in	.5
Vertical Location (**V**)	13in	.87
Travel Distance (**D**)	7in	1
Angle of Assymetry (**A**)	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	Fair	1
Frequency - (**F**)	20/hr	.81
Average load lifted (**L**) (lbs)	12.5kg	
Max Load Lifted (**L**) (lbs)	12.5kg	
Duration (**D**) (**1**-short, 2- Moderate, 8 - long)	8 hrs	1
RWL = 23 xHM x VM x DM x AM x FM x CM		8.10 kg
Lifting index		1.48
Status		Risky

Appendix 11: WISHA Lifting Calculator -Job Analysis Sheet for job 2

WISHA Lifting Calculator -Job Analysis Sheet

Job No	2

Actual weight	12.5 kg
Unadjusted Weight Limit	35lb
Lifts per Minute	0.33
Hours per Day	8
Twisting	0



Unadjusted weight Limit x	35lb
Twisting Adjustment	1
Adjusted Weight Limit x	35lb
Limit Reduction Multiplier	.85
Weight Limit	29.75lb(13.5kg)

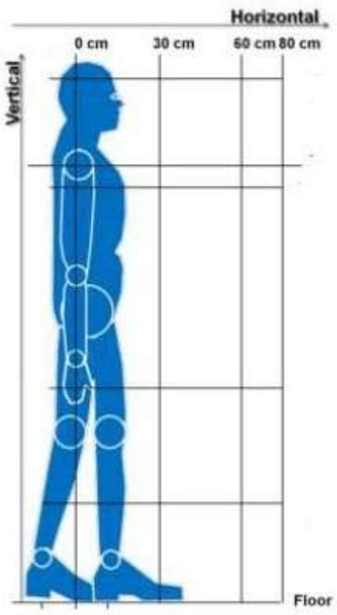
Weight Limit	13.5
Actual Weight	12.5
Lifting Index	0.925
Status	Not Risky

Appendix 12: ACGIH Lifting TLV calculator -Job Analysis Sheet for job 2

ACGIH Lifting Threshold Limit Values calculator -Job Analysis Sheet

Job No	2

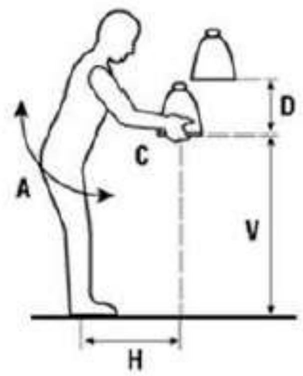
ACGIH Lifting Variable	Value
Weight	12.5kg
Lifting frequency	20 lift/hr
Vertical Zone	13 inches
Horizontal zone	20 inches
Lifting TLV	14 kg
Lifting index	0.89
Status	Not Risky



Appendix 13: NIOSH Lifting Equation calculator -Job Analysis Sheet for job 3

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	3



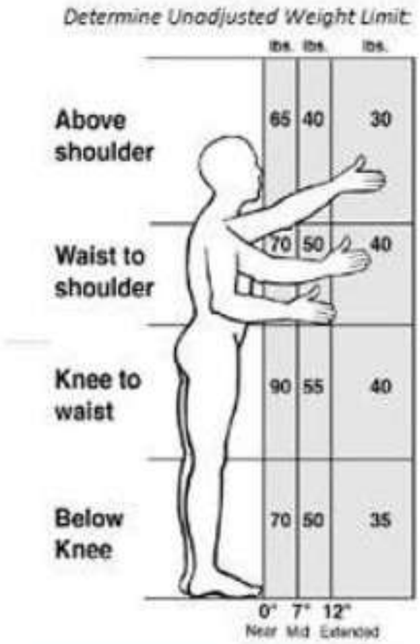
NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**)	10in	1
Vertical Location (**V**)	40in	.92
Travel Distance (**D**)	34in	.87
Angle of Assymetry (**A**)	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	Fair	0.95
Frequency - (**F**)	10/hr	.85
Average load lifted (**L**) (lbs)	25kg	
Max Load Lifted (**L**) (lbs)	25kg	
Duration (**D**) (**1**-short, 2- Moderate, 8 - long)	8 hrs	1
RWL = 23 xHM x VM x DM x AM x FM x CM		14.9kg
Lifting index		1.74
Status		Risky

Appendix 14: WISHA Lifting Calculator -Job Analysis Sheet for job 3

WISHA Lifting Calculator -Job Analysis Sheet

Job No	3

Actual weight	25 kg
unadjusted Weight Limit	55 lb
Lifts per Minute	.16
Hours per Day	8
Twisting	0



Unadjusted weight Limit x	55lb
Twisting Adjustment	1
Adjusted Weight Limit x	55lb
Limit Reduction Multiplier	.85
Weight Limit	46.75lb(21.22kg)

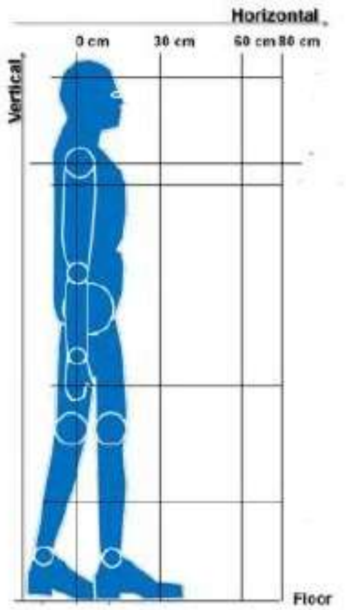
Weight Limit	21.22
Actual Weight	25
Lifting Index	1.17
Status	Risky

Appendix 15: ACGIH Lifting TLV calculator -Job Analysis Sheet for job 3

ACGIH Lifting Threshold Limit Values calculator -Job Analysis Sheet

Job No: 3

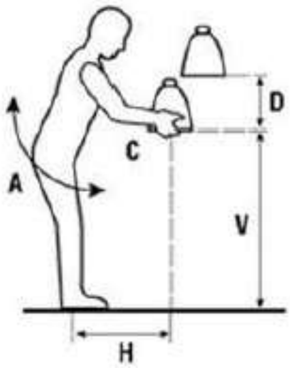
ACGIH Lifting Variable	Value
Weight	25kg
Lifting frequency	10 lift/hr
Vertical Zone	40 inches
Horizontal zone	10 inches
Lifting TLV	32kg
Lifting index	0.78
Status	safe



Appendix 16: NIOSH Lifting Equation calculator -Job Analysis Sheet for job 4

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	4



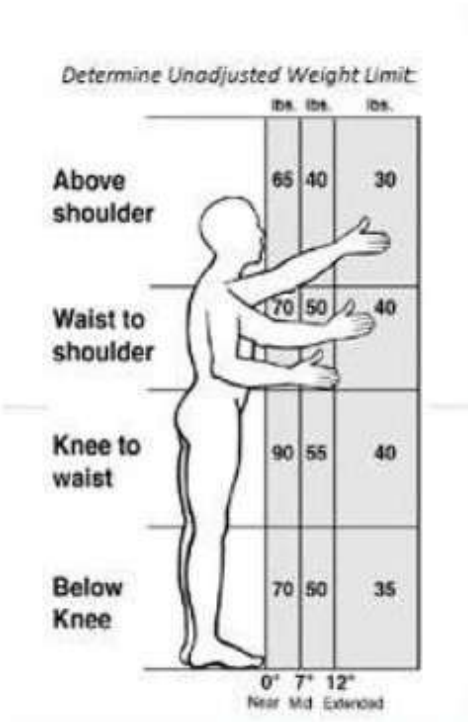
NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**)	18in	.55
Vertical Location (**V**)	36in	.95
Travel Distance (**D**)	30in	.88
Angle of Assymetry (**A**)	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	Fair	0.95
Frequency - (**F**)	10/hr	.85
Average load lifted (**L**) (lbs)	10kg	
Max Load Lifted (**L**) (lbs)	10kg	
Duration (**D**) (1-short, 2- Moderate, 8 - long)	8 hrs	1
RWL = 23 xHM x VM x DM x AM x FM x CM		8.53kg
Lifting index		1.17
Status		Risky

Appendix 17: WISHA Lifting Calculator -Job Analysis Sheet for job 4

WISHA Lifting Calculator -Job Analysis Sheet

Job No	4

Actual weight	10 kg
Unadjusted Weight Limit	40lb
Lifts per Minute	.13
Hours per Day	8
Twisting	0



Unadjusted weight Limit x	40lb
Twisting Adjustment	1
Adjusted Weight Limit x	40lb
Limit Reduction Multiplier	.85
Weight Limit	34lb(15.43kg)

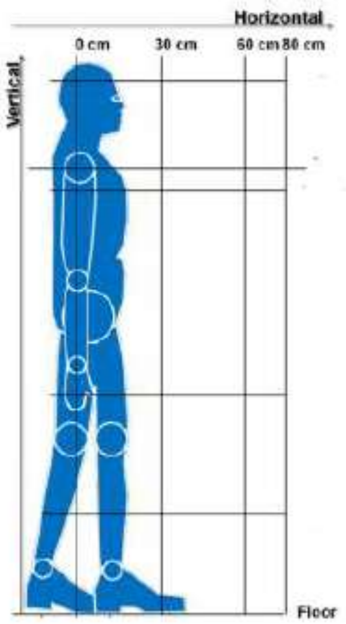
Weight Limit	16.43 kg
Actual Weight	10
Lifting Index	0.65
Status	Not Risky

Appendix 18: ACGIH Lifting TLV calculator -Job Analysis Sheet for job 4

ACGIH Lifting Threshold Limit Values calculator -Job Analysis Sheet

Job No 4

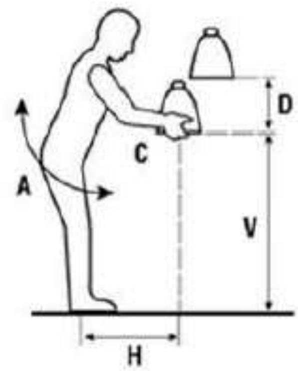
ACGIH Lifting Variable	**Value**
Weight	10kg
Lifting frequency	8 lift/hr
Vertical Zone	36 inches
Horizontal zone	18 inches
Lifting TLV	14kg
Lifting index	0.71
Status	Not risky



Appendix 19: NIOSH Lifting Equation calculator -Job Analysis Sheet for job 5

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	5



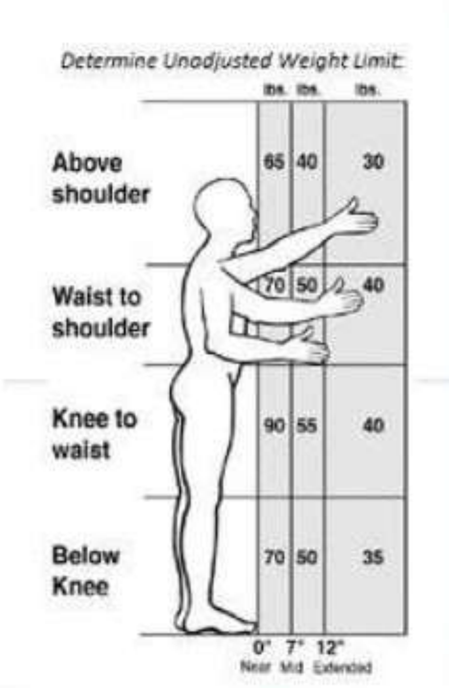
NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**)	10in	1
Vertical Location (**V**)	50in	.85
Travel Distance (**D**)	44in	.86
Angle of Assymetry (**A**)	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	Fair	0.95
Frequency - (**F**)	10/hr	.85
Average load lifted (**L**) (lbs)	25kg	
Max Load Lifted (**L**) (lbs)	25kg	
Duration (**D**) (**1**-short, 2- Moderate, 8 - long)	8 hrs	
RWL = 23 xHM x VM x DM x AM x FM x CM		13.57kg
Lifting index		1.84
Status		Risky

Appendix 20: WISHA Lifting Calculator -Job Analysis Sheet for job 5

WISHA Lifting Calculator -Job Analysis Sheet

Job No	5

Actual weight	25 kg
Unadjusted Weight Limit	50lb
Lifts per Minute	.16
Hours per Day	8
Twisting	0



Unadjusted weight Limit x	50lb
Twisting Adjustment	1
Adjusted Weight Limit x	50lb
Limit Reduction Multiplier	.85
Weight Limit	42.5lb(19.2)

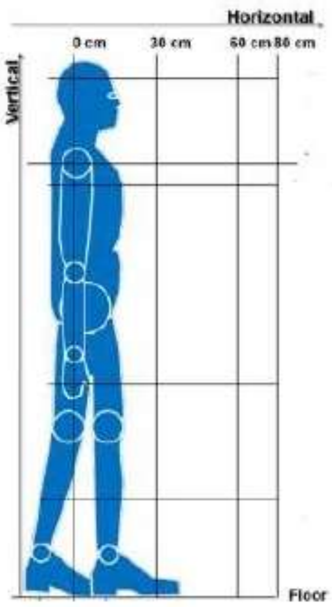
Weight Limit	19.2 kg
Actual Weight	25
Lifting Index	1.30
Status	Risky

Appendix 21: ACGIH Lifting TLV calculator -Job Analysis Sheet for job 5

ACGIH Lifting Threshold Limit Values calculator -Job Analysis Sheet

Job No: 5

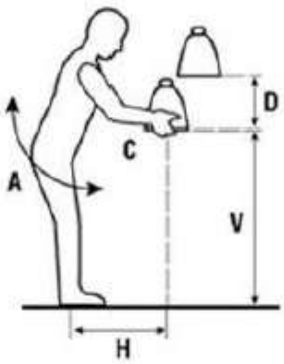
ACGIH Lifting Variable	Value
Weight	25 kg
Lifting frequency	10 lift/hr
Vertical Zone	50 inches
Horizontal zone	10 inches
Lifting TLV	32 kg
Lifting index	0.78
Status	Not Risky



Appendix 22: NIOSH Lifting Equation calculator -Job Analysis Sheet for job 6

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	6



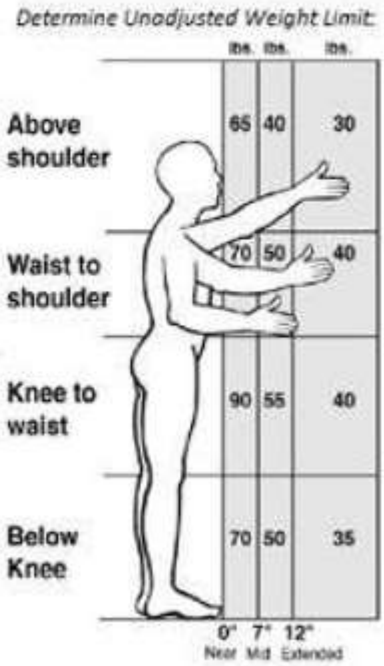
NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**)	14in	0.71
Vertical Location (**V**)	45in	.89
Travel Distance (**D**)	39in	.87
Angle of Assymetry (**A**)	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	Fair	0.95
Frequency - (**F**)	10/hr	.85
Average load lifted (**L**) (lbs)	20kg	
Max Load Lifted (**L**) (lbs)	20kg	
Duration (**D**) (1-short, 2- Moderate, 8 - long)	8 hrs	
RWL = 23 xHM x VM x DM x AM x FM x CM		14.38
Lifting index		1.39
Status		Risky

Appendix 23: WISHA Lifting Calculator -Job Analysis Sheet for job 6

WISHA Lifting Calculator -Job Analysis Sheet

Job No	6

Actual weight	20 kg
Unadjusted Weight Limit	40lb
Lifts per Minute	.16
Hours per Day	8
Twisting	0



Unadjusted weight Limit x	50lb
Twisting Adjustment	1
Adjusted Weight Limit x	50lb
Limit Reduction Multiplier	.85
Weight Limit	34lb(19.2)

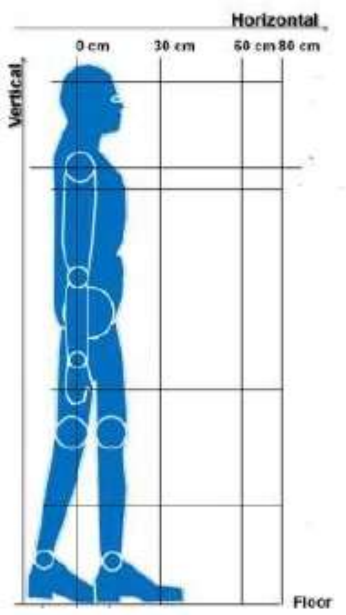
Weight Limit	15.43 kg
Actual Weight	25
Lifting Index	1.30
Status	Risky

Appendix 24: ACGIH Lifting TLV calculator -Job Analysis Sheet for job 6

ACGIH Lifting Threshold Limit Values calculator -Job Analysis Sheet

Job No 6

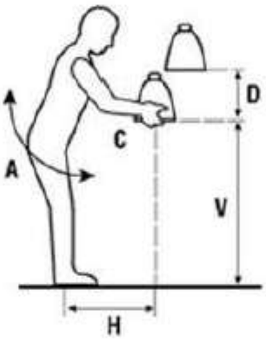
ACGIH Lifting Variable	Value
Weight	20
Lifting frequency	10 lift/hr
Vertical Zone	45 inches
Horizontal zone	14 inches
Lifting TLV	16 kg
Lifting index	1.25
Status	Risky



Appendix 25: NIOSH Lifting Equation calculator -Job Analysis Sheet for job 7

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	7



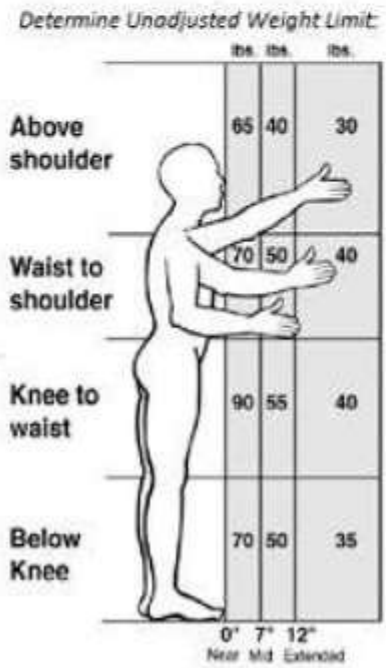
NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**)	10in	1
Vertical Location (**V**)	16in	.90
Travel Distance (**D**)	8in	1
Angle of Assymetry (**A**)	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	Fair	1
Frequency - (**F**)	12/hr	.85
Average load lifted (**L**) (lbs)		15kg
Max Load Lifted (**L**) (lbs)		15kg
Duration (**D**) (**1**-short, 2- Moderate, 8 - long)	8 hrs	1
RWL = 23 xHM x VM x DM x AM x FM x CM		17.6 kg
Lifting index		0.85
Status		Not Risky

Appendix 26: WISHA Lifting Calculator -Job Analysis Sheet for job 7

WISHA Lifting Calculator -Job Analysis Sheet

Job No	7

Actual weight	15 kg
Unadjusted Weight Limit	50lb
Lifts per Minute	0.2
Hours per Day	8
Twisting	0



Unadjusted weight Limit x	50lb
Twisting Adjustment	1
Adjusted Weight Limit x	50lb
Limit Reduction Multiplier	.85
Weight Limit	42.5lb(19.3kg)

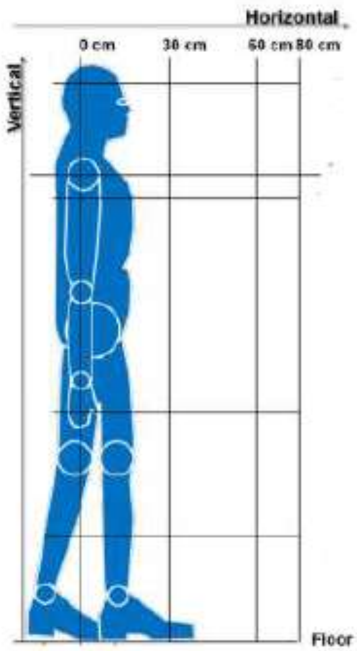
Weight Limit	19.3
Actual Weight	15
Lifting Index	0.78
Status	Not Risky

Appendix 27: ACGIH Lifting TLV calculator -Job Analysis Sheet for job 7

ACGIH Lifting Threshold Limit Values calculator -Job Analysis Sheet

Job No: 7

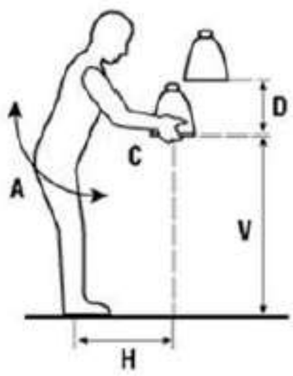
ACGIH Lifting Variable	Value
Weight	15kg
Lifting frequency	12 lift/hr
Vertical Zone	16 inches
Horizontal zone	10 inches
Lifting TLV	18 kg
Lifting index	0.83
Status	Not Risky



Appendix 28: NIOSH Lifting Equation calculator -Job Analysis Sheet for job 8

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	8



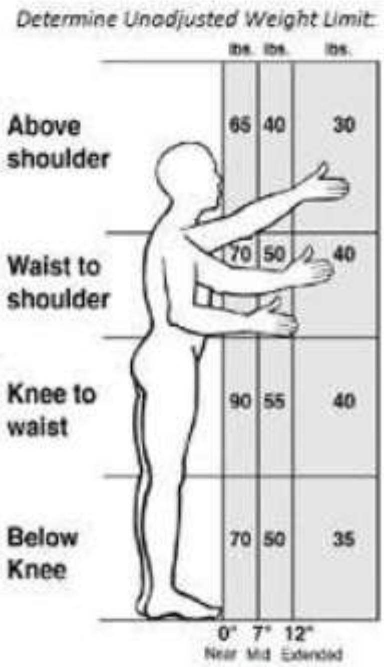
NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**)	16in	0.62
Vertical Location (**V**)	30in	1
Travel Distance (**D**)	22in	.90
Angle of Assymetry (**A**)	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	Fair	1
Frequency - (**F**)	12/hr	.85
Average load lifted (**L**) (lbs)		12.5kg
Max Load Lifted (**L**) (lbs)		12.5kg
Duration (**D**) (**1**-short, 2- Moderate, 8 - long)	8 hrs	1
RWL = 23 xHM x VM x DM x AM x FM x CM		10.9 kg
Lifting index		1.15
Status		Risky

Appendix 29: WISHA Lifting Calculator -Job Analysis Sheet for job 8

WISHA Lifting Calculator -Job Analysis Sheet

Job No	8

Actual weight	15 kg
Unadjusted Weight Limit	40lb
Lifts per Minute	0.2
Hours per Day	8
Twisting	0



Unadjusted weight Limit x	50lb
Twisting Adjustment	1
Adjusted Weight Limit x	50lb
Limit Reduction Multiplier	.85
Weight Limit	34(15.43kg)

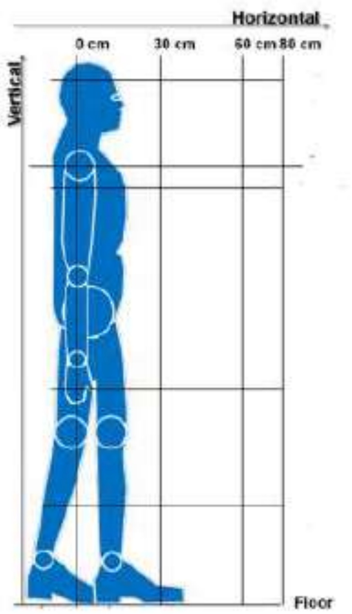
Weight Limit	15.43
Actual Weight	12.5
Lifting Index	0.81
Status	Not Risky

Appendix 30: ACGIH Lifting TLV calculator -Job Analysis Sheet for job 8

ACGIH Lifting Threshold Limit Values calculator -Job Analysis Sheet

Job No: 8

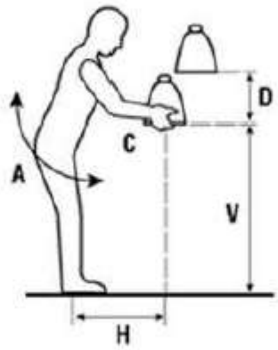
ACGIH Lifting Variable	Value
Weight	12.5kg
Lifting frequency	12 lift/hr
Vertical Zone	16 inches
Horizontal zone	10 inches
Lifting TLV	14 kg
Lifting index	0.89
Status	Not Risky



Appendix 31: NIOSH Lifting Equation calculator -Job Analysis Sheet for job 9

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	9



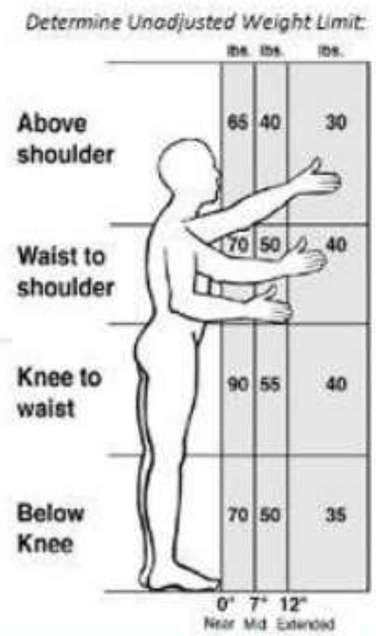
NIOSH Lifting Variable	**Value**	**Multiplier**
Horizontal Location (**H**)	18in	0.56
Vertical Location (**V**)	15in	0.89
Travel Distance (**D**)	9in	1
Angle of Assymetry (**A**)	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	2	1
Frequency - (**F**)	12/hr	0.85
Average load lifted (**L**) (lbs)	15kg	
Max Load Lifted (**L**) (lbs)	15 kg	
Duration (**D**) (**1**-short, 2- Moderate, 8 - long)	8 hrs	
RWL = 23 xHM x VM x DM x AM x FM x CM		10.14kg
Lifting index		1.48
Status		Risky

Appendix 32: WISHA Lifting Calculator -Job Analysis Sheet for job 9

WISHA Lifting Calculator -Job Analysis Sheet

Job No	9

Actual weight	15kg
Unadjusted Weight Limit	35 lb
Lifts per Minute	0.2
Hours per Day	8
Twisting	0



Unadjusted weight Limit x	35 lb
Twisting Adjustment	1
Adjusted Weight Limit x	35 lb
Limit Reduction Multiplier	0.85
Weight Limit	29.92lb(13.62kg)

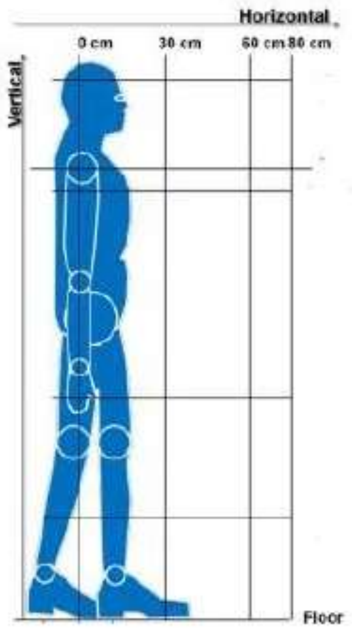
Weight Limit	13.62 kg
Actual Weight	15kg
Lifting Index	1.10
Status	Risky

Appendix 33: ACGIH Lifting TLV calculator -Job Analysis Sheet for job 9

ACGIH Lifting Threshold Limit Values calculator -Job Analysis Sheet

Job No 9

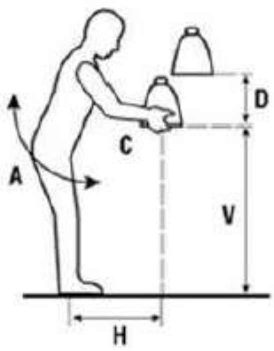
ACGIH Lifting Variable	Value
Weight	15
Lifting frequency	12
Vertical Zone	15
Horizontal zone	18
Lifting TLV	14
Lifting index	1.07
Status	Risky



Appendix 34: NIOSH Lifting Equation calculator -Job Analysis Sheet for job 10

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	10



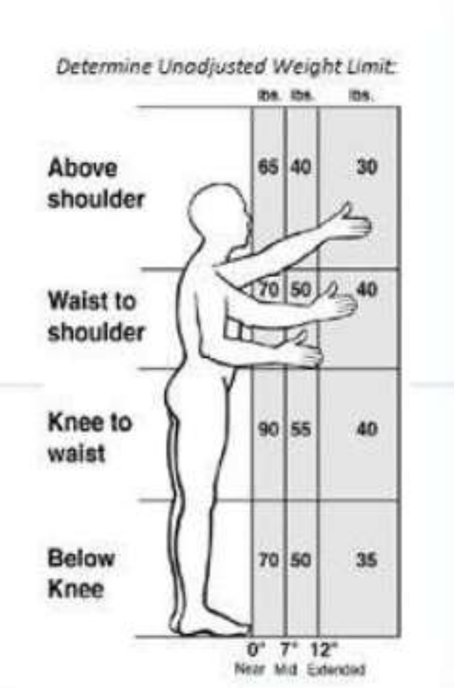
NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**)	8 in	1
Vertical Location (**V**)	48 in	0.87
Travel Distance (**D**)	42in	0.86
Angle of Asymmetry (**A**)	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	2	0.95
Frequency - (**F**)	11	0.85
Average load lifted (**L**) (lbs)	25kg	
Max Load Lifted (**L**) (lbs)	25kg	
Duration (**D**) (1-short, 2- Moderate, 8 - long)		
RWL = 23 xHM x VM x DM x AM x FM x CM		13.89
Lifting index		1.8
Status		Risky

Appendix 35: WISHA Lifting Calculator -Job Analysis Sheet for job 10

WISHA Lifting Calculator -Job Analysis Sheet

Job No	10

Actual weight	25 kg
Unadjusted Weight Limit	50 lb
Lifts per Minute	11/hr
Hours per Day	8
Twisting	0



Unadjusted weight Limit x	50lb
Twisting Adjustment	1
Adjusted Weight Limit x	50lb
Limit Reduction Multiplier	1
Weight Limit	50 lb(22.7kg)

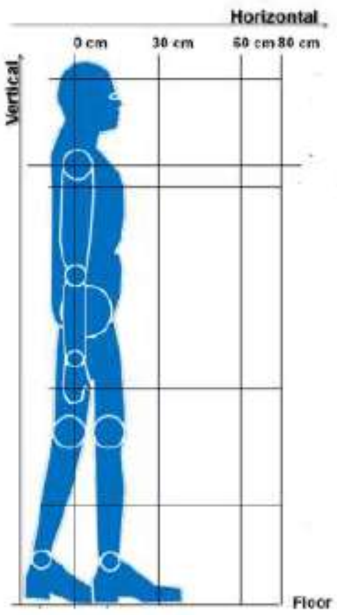
Weight Limit	22.7kg
Actual Weight	25kg
Lifting Index	1.10
Status	Risky

Appendix 36: ACGIH Lifting TLV calculator -Job Analysis Sheet for job 10

ACGIH Lifting Threshold Limit Values calculator -Job Analysis Sheet

Job No 10

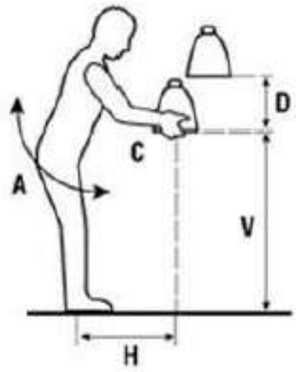
ACGIH Lifting Variable	Value
Weight	25kg
Lifting frequency	11/hr
Vertical Zone	48in
Horizontal zone	8 in
Lifting TLV	32kg
Lifting index	0.78
Status	Not risky



Appendix 37: NIOSH Lifting Equation calculator -Job Analysis Sheet for job 9

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	11



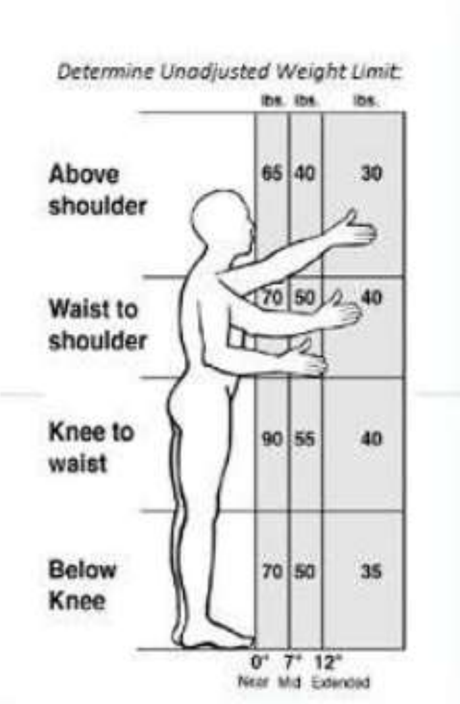
NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**)	17in	0.59
Vertical Location (**V**)	48in	0.86
Travel Distance (**D**)	42in	0.86
Angle of Assymetry (**A**)	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	2	0.95
Frequency - (**F**)	10/hr	0.85
Average load lifted (**L**) (lbs)		12.5kg
Max Load Lifted (**L**) (lbs)		12.5kg
Duration (**D**) (**1**-short, 2- Moderate, 8 - long)		
RWL = 23 xHM x VM x DM x AM x FM x CM		8.15
Lifting index		1.53
Status		Risky

Appendix 38: WISHA Lifting Calculator -Job Analysis Sheet for job 11

WISHA Lifting Calculator -Job Analysis Sheet

Job No	11

Actual weight	12.5
Unadjusted Weight Limit	40lb
Lifts per Minute	10/hr
Hours per Day	8
Twisting	0



Unadjusted weight Limit x	40lb
Twisting Adjustment	1
Adjusted Weight Limit x	40lb
Limit Reduction Multiplier	1
Weight Limit	40lb(18.16kg)

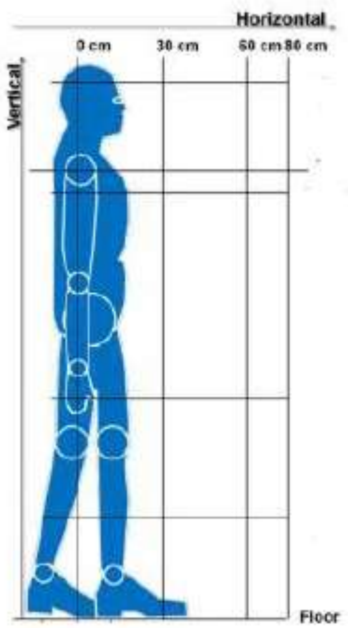
Weight Limit	18.16
Actual Weight	12.5
Lifting Index	0.69
Status	Not risky

Appendix 39: ACGIH Lifting TLV calculator -Job Analysis Sheet for job 11

ACGIH Lifting Threshold Limit Values calculator -Job Analysis Sheet

Job No 11

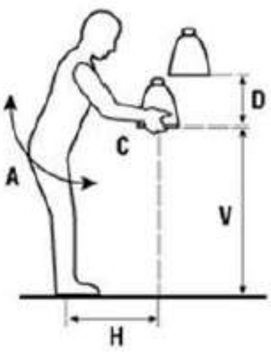
ACGIH Lifting Variable	Value
Weight	15kg
Lifting frequency	10/hr
Vertical Zone	48in
Horizontal zone	17in
Lifting TLV	16kg
Lifting index	0.78
Status	safe



Appendix 40: NIOSH Lifting Equation calculator -Job Analysis Sheet for job 12

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	12



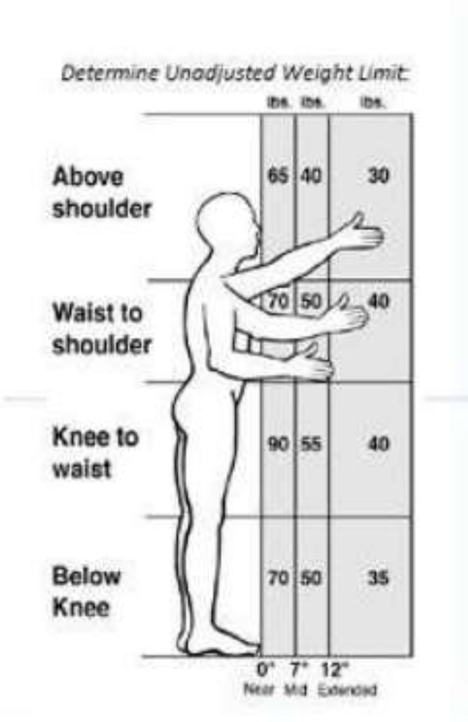
NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**)	16 in	0.62
Vertical Location (**V**)	46 in	0.88
Travel Distance (**D**)	40 in	0.86
Angle of Assymetry (**A**)	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	2	0.95
Frequency - (**F**)	9/hr	0.85
Average load lifted (**L**) (lbs)	10kg	
Max Load Lifted (**L**) (lbs)	10kg	
Duration (**D**) (1-short, 2- Moderate, 8 - long)	8hrs	
RWL = 23 xHM x VM x DM x AM x FM x CM		8.84 kg
Lifting index		1.13
Status		risky

Appendix 41: WISHA Lifting Calculator -Job Analysis Sheet for job 12

WISHA Lifting Calculator -Job Analysis Sheet

Job No	12

Actual weight	10kg
Unadjusted Weight Limit	40 lb
Lifts per Minute	9/hr
Hours per Day	8
Twisting	0



Unadjusted weight Limit x	40lb
Twisting Adjustment	1
Adjusted Weight Limit x	40lb
Limit Reduction Multiplier	1
Weight Limit	40lb(18.16kg)

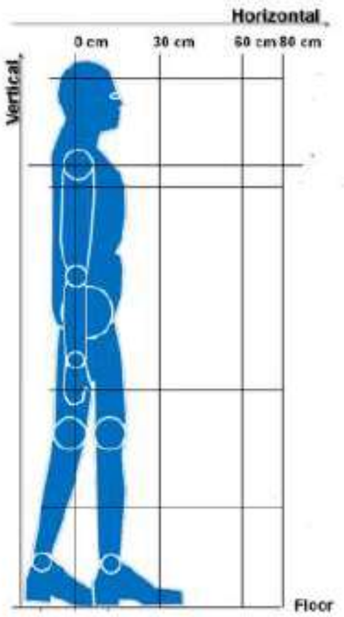
Weight Limit	18.16kg
Actual Weight	10 kg
Lifting Index	0.55
Status	Not risky

Appendix 42: ACGIH Lifting TLV calculator -Job Analysis Sheet for job 12

ACGIH Lifting Threshold Limit Values calculator -Job Analysis Sheet

Job No 12

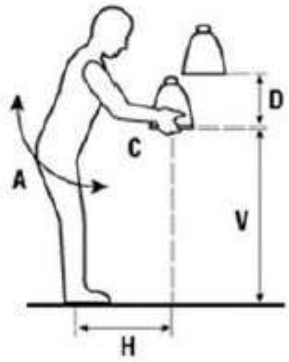
ACGIH Lifting Variable	Value
Weight	10kg
Lifting frequency	9/hr
Vertical Zone	46 in
Horizontal zone	16 in
Lifting TLV	16kg
Lifting index	0.625
Status	Not risky



Appendix 43: NIOSH Lifting Equation calculator -Job Analysis Sheet for job A

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	Job A



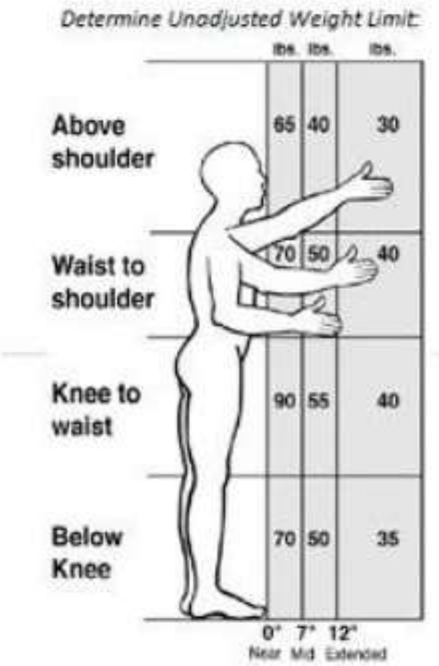
NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**) cm	20	1
Vertical Location (**V**) cm	50	0.92
Travel Distance (**D**) cm	25	1
Angle of Asymmetry (**A**) Degrees	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	1	1
Frequency - (**F**) Lifts/hour	12	0.85
Load lifted (**L**) kg	19.3	19.3 kg
Duration (**D**) (1-short, 2- Moderate, 8 - long)	8 hrs	
RWL = 23 xHM x VM x DM x AM x FM x CM		18.1 kg
Lifting index		1.07
Status		Risky

Appendix 44: WISHA Lifting Calculator -Job Analysis Sheet for job A

WISHA Lifting Calculator -Job Analysis Sheet

Job No	Job A

Actual weight (kg)	19.3 kg
Unadjusted Weight Limit (lb)	50
Unadjusted Weight Limit (kg)	22.7
Lifts per Minute	12/hr
Hours per Day	8 hr
Twisting	0
Horizontal distance (cm)	20
Vertical distance (cm)	50



Unadjusted weight Limit (kg) x	22.7
Twisting Adjustment	1
Adjusted Weight Limit (kg) x	22.7
Limit Reduction Multiplier	0.85
Weight Limit (kg)	19.3

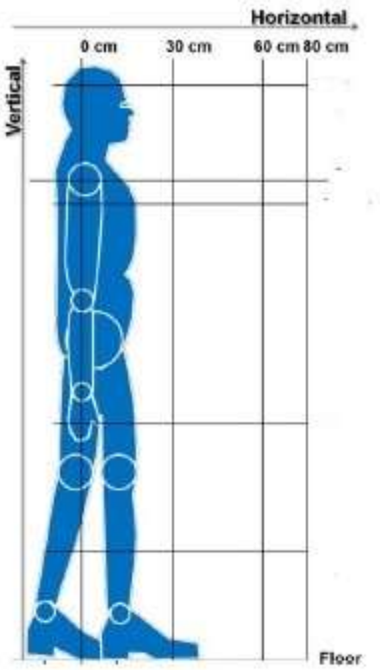
Actual Weight(kg)/	19.3
Weight Limit(kg)	19.3
Lifting Index	1
Status	Not Risky

Appendix 45: ACGIH Lifting TLV calculator -Job Analysis Sheet for job A

ACGIH Lifting Threshold Limit Values calculator -Job Analysis Sheet

Job No | Job A

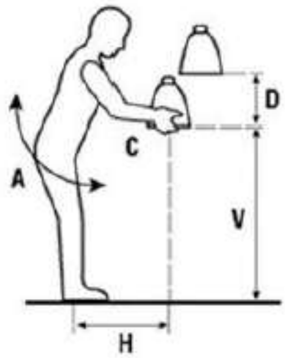
ACGIH Lifting Variable	Value
Weight (kg)	19.3
Lifting frequency (lifts per hour)	12
Vertical Zone (cm)	50
Horizontal zone (cm)	20
Lifting TLV (kg)	18
Lifting index	1.07
Status	Risky



Appendix 46: NIOSH Lifting Equation calculator -Job Analysis Sheet for job B

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	Job B

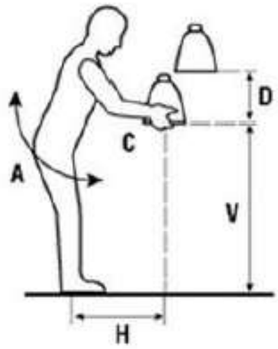


NIOSH Lifting Variable	**Value**	**Multiplier**
Horizontal Location (**H**) cm	30	0.83
Vertical Location (**V**) cm	50	0.92
Travel Distance (**D**) cm	25	1
Angle of Asymmetry (**A**) Degrees	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	1	1
Frequency - (**F**) Lifts/hour	12	0.85
Load lifted (**L**) kg	15.1	15.1 kg
Duration (**D**) (1-short, 2- Moderate, 8 - long)	8 hrs	
RWL = 23 xHM x VM x DM x AM x FM x CM		15.1 kg
Lifting index		1
Status		Not Risky

Appendix 47: NIOSH Lifting Equation calculator -Job Analysis Sheet for job C

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	Job C



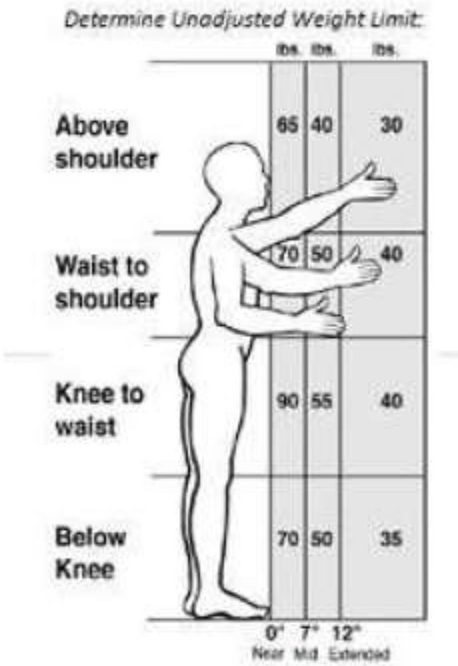
NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**) cm	20	1
Vertical Location (**V**) cm	100	0.92
Travel Distance (**D**) cm	50	0.91
Angle of Asymmetry (**A**) Degrees	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	1	1
Frequency - (**F**) Lifts/hour	12	0.85
Load lifted (**L**) kg	21.2	21. 2 kg
Duration (**D**) (**1**-short, 2- Moderate, 8 - long)	8 hrs	
RWL = 23 xHM x VM x DM x AM x FM x CM		16.5 kg
Lifting index		1.3
Status		Risky

Appendix 48: WISHA Lifting Calculator -Job Analysis Sheet for job C

WISHA Lifting Calculator -Job Analysis Sheet

Job No	Job C

Actual weight (kg)	21.3 kg
Unadjusted Weight Limit (lb)	55
Unadjusted Weight Limit (kg)	24.97
Lifts per Minute	12/hr
Hours per Day	8 hr
Twisting	0
Horizontal distance (cm)	20
Vertical distance (cm)	50



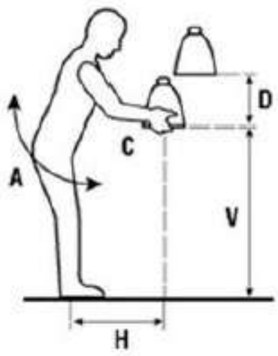
Unadjusted weight Limit (kg) x	24.97
Twisting Adjustment	1
Adjusted Weight Limit (kg) x	24.97
Limit Reduction Multiplier	0.85
Weight Limit (9kg)	42.5lb

Actual Weight(kg)/	21.3
Weight Limit(kg)	21.3
Lifting Index	1
Status	Not Risky

Appendix 49: NIOSH Lifting Equation calculator -Job Analysis Sheet for job D

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	Job D

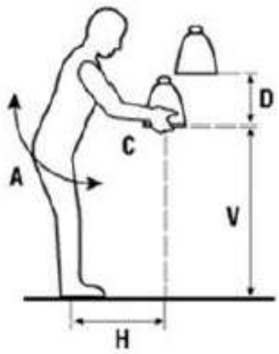


NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**) cm	30	0.83
Vertical Location (**V**) cm	100	0.92
Travel Distance (**D**) cm	50	0.91
Angle of Asymmetry (**A**) Degrees	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	1	1
Frequency - (**F**) Lifts/hour	12	0.85
Load lifted (**L**) kg	13.7	13.7 kg
Duration (**D**) (**1**-short, 2- Moderate, 8 - long)	8 hrs	
RWL = 23 xHM x VM x DM x AM x FM x CM		13.7 kg
Lifting index		1
Status		Not Risky

Appendix 50: NIOSH Lifting Equation calculator -Job Analysis Sheet for job E

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	Job E



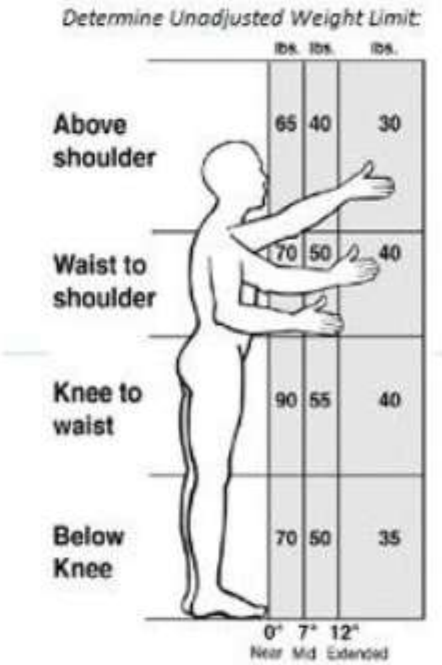
NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**) cm	20	1
Vertical Location (**V**) cm	150	0.77
Travel Distance (**D**) cm	50	0.91
Angle of Asymmetry (**A**) Degrees	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	1	1
Frequency - (**F**) Lifts/hour	12	0.85
Load lifted (**L**) kg	19.3	19.3 kg
Duration (**D**) (**1**-short, 2- Moderate, 8 - long)	8 hrs	
RWL = 23 xHM x VM x DM x AM x FM x CM		13.8 kg
Lifting index		1.37
Status		Risky

Appendix 51: WISHA Lifting Calculator -Job Analysis Sheet for job E

WISHA Lifting Calculator -Job Analysis Sheet

Job No	Job E

Actual weight (kg)	19.3 kg
Unadjusted Weight Limit (lb)	50
Unadjusted Weight Limit (kg)	22.7
Lifts per Minute	12/hr
Hours per Day	8 hr
Twisting	0
Horizontal distance (cm)	20
Vertical distance (cm)	150



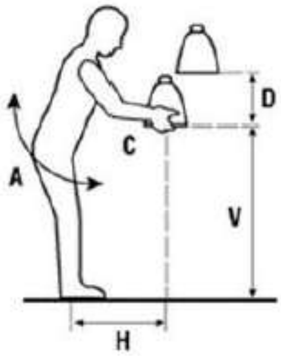
Unadjusted weight Limit (kg) x	22.7
Twisting Adjustment	1
Adjusted Weight Limit (kg) x	22.7
Limit Reduction Multiplier	0.85
Weight Limit (kg)	19.3

Actual Weight(kg)/	19.3
Weight Limit(kg)	19.3
Lifting Index	1
Status	Not Risky

Appendix 52: NIOSH Lifting Equation calculator -Job Analysis Sheet for job F

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	Job F

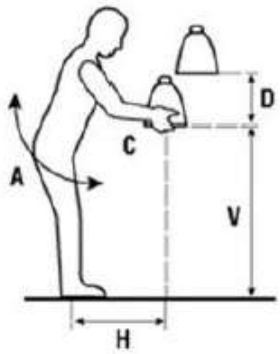


NIOSH Lifting Variable	**Value**	**Multiplier**
Horizontal Location (**H**) cm	30	0.83
Vertical Location (**V**) cm	150	0.77
Travel Distance (**D**) cm	50	0.91
Angle of Asymmetry (**A**) Degrees	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	1	1
Frequency - (**F**) Lifts/hour	12	0.85
Load lifted (**L**) kg	11.5	11.5 kg
Duration (**D**) (**1**-short, 2- Moderate, 8 - long)	8 hrs	
RWL = 23 xHM x VM x DM x AM x FM x CM		11.5 kg
Lifting index		1
Status		Risky

Appendix 53: NIOSH Lifting Equation calculator -Job Analysis Sheet for job G

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	Job G



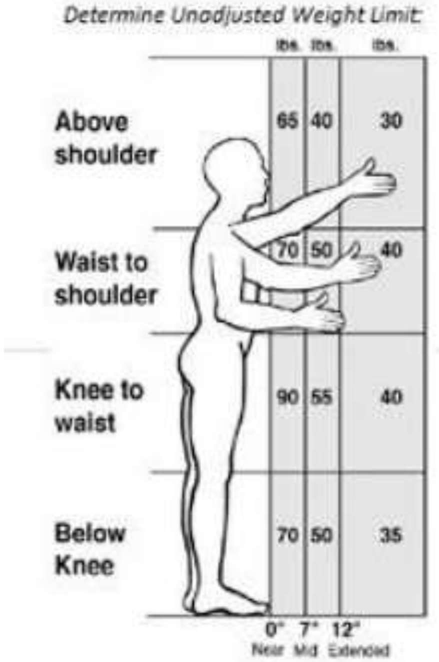
NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**) cm	30	0.83
Vertical Location (**V**) cm	50	0.92
Travel Distance (**D**) cm	25	1
Angle of Asymmetry (**A**) Degrees	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	1	1
Frequency - (**F**) Lifts/hour	12	0.85
Load lifted (**L**) kg	19.3	19.3 kg
Duration (**D**) (1-short, 2- Moderate, 8 - long)	8 hrs	
RWL = 23 xHM x VM x DM x AM x FM x CM		15.1 kg
Lifting index		1.28
Status		Risky

Appendix 54: WISHA Lifting Calculator -Job Analysis Sheet for job G

WISHA Lifting Calculator -Job Analysis Sheet

Job No	Job G

Actual weight (kg)	19.3 kg
Unadjusted Weight Limit (lb)	50
Unadjusted Weight Limit (kg)	22.7
Lifts per Minute	12/hr
Hours per Day	8 hr
Twisting	0
Horizontal distance (cm)	30
Vertical distance (cm)	50



Unadjusted weight Limit (kg) x	22.7
Twisting Adjustment	1
Adjusted Weight Limit (kg) x	22.7
Limit Reduction Multiplier	0.85
Weight Limit (kg)	19.3

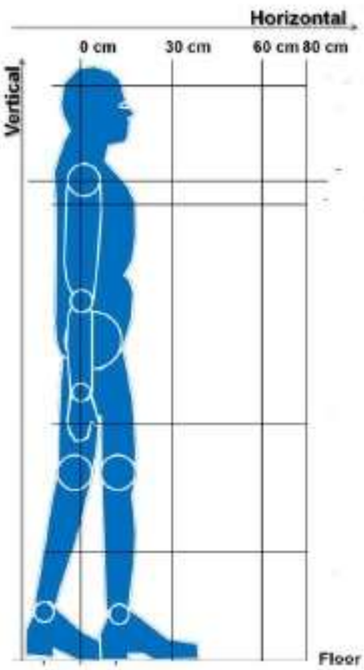
Actual Weight(kg)/	19.3
Weight Limit(kg)	19.3
Lifting Index	1
Status	Not Risky

Appendix 55: ACGIH Lifting TLV calculator -Job Analysis Sheet for job G

ACGIH Lifting Threshold Limit Values calculator -Job Analysis Sheet

Job No | Job G

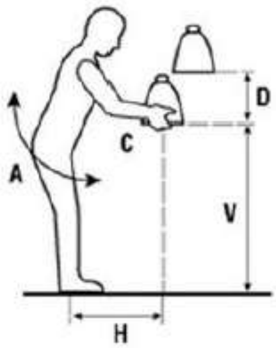
ACGIH Lifting Variable	Value
Weight (kg)	19.3
Lifting frequency (lifts per hour)	12
Vertical Zone (cm)	50
Horizontal zone (cm)	30
Lifting TLV (kg)	18
Lifting index	1.07
Status	Risky



Appendix 56: NIOSH Lifting Equation calculator -Job Analysis Sheet for job H

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	Job H

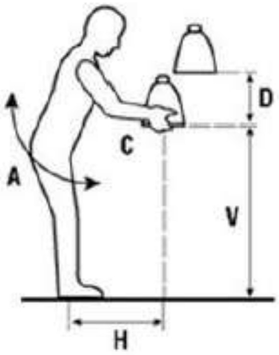


NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**) cm	50	0.5
Vertical Location (**V**) cm	50	0.92
Travel Distance (**D**) cm	25	1
Angle of Asymmetry (**A**) Degrees	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	1	1
Frequency - (**F**) Lifts/hour	12	0.85
Load lifted (**L**) kg	9.0	9.0 kg
Duration (**D**) (**1**-short, 2- Moderate, 8 - long)	8 hrs	
RWL = 23 xHM x VM x DM x AM x FM x CM		9.0 kg
Lifting index		1
Status		Not Risky

Appendix 57: NIOSH Lifting Equation calculator -Job Analysis Sheet for job I

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	Job I



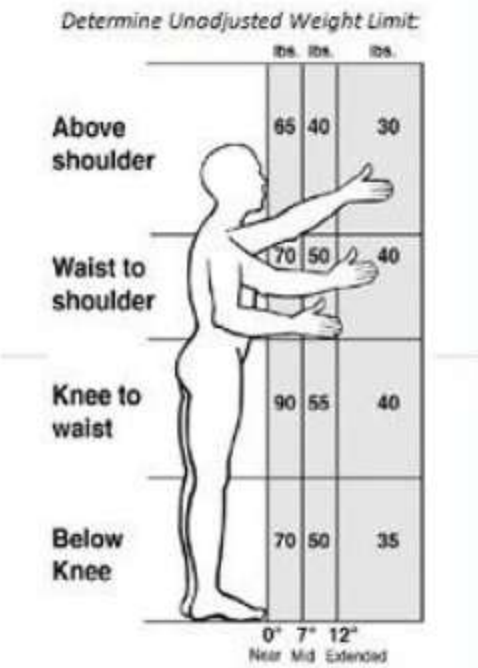
NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**) cm	30	0.83
Vertical Location (**V**) cm	100	0.92
Travel Distance (**D**) cm	50	0.91
Angle of Asymmetry (**A**) Degrees	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	1	1
Frequency - (**F**) Lifts/hour	12	0.85
Load lifted (**L**) kg	21.2	21. 2 kg
Duration (**D**) (1-short, 2- Moderate, 8 - long)	8 hrs	
RWL = 23 xHM x VM x DM x AM x FM x CM		13.7 kg
Lifting index		1.54
Status		Risky

Appendix 58: WISHA Lifting Calculator -Job Analysis Sheet for job I

WISHA Lifting Calculator -Job Analysis Sheet

Job No	Job I

Actual weight (kg)	21.3 kg
Unadjusted Weight Limit (lb)	55
Unadjusted Weight Limit (kg)	24.97
Lifts per Minute	12/hr
Hours per Day	8 hr
Twisting	0
Horizontal distance (cm)	30
Vertical distance (cm)	50



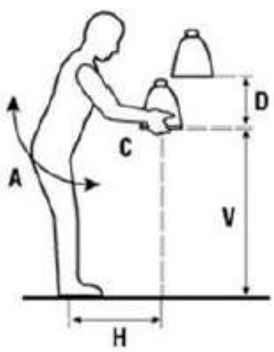
Unadjusted weight Limit (kg) x	24.97
Twisting Adjustment	1
Adjusted Weight Limit (kg) x	24.97
Limit Reduction Multiplier	0.85
Weight Limit (kg)	21.2

Actual Weight(kg)/	21.2
Weight Limit(kg)	21.2
Lifting Index	1
Status	Not Risky

Appendix 59: NIOSH Lifting Equation calculator -Job Analysis Sheet for job J

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	Job J

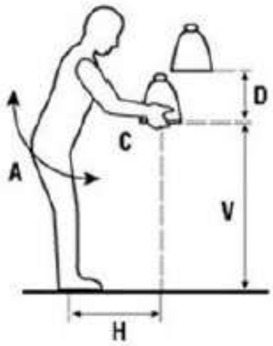


NIOSH Lifting Variable	**Value**	**Multiplier**
Horizontal Location (**H**) cm	50	0.5
Vertical Location (**V**) cm	100	0.92
Travel Distance (**D**) cm	50	0.91
Angle of Asymmetry (**A**) Degrees	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	1	1
Frequency - (**F**) Lifts/hour	12	0.85
Load lifted (**L**) kg	8.2	8.2 kg
Duration (**D**) (1-short, 2- Moderate, 8 - long)	8 hrs	
RWL = 23 xHM x VM x DM x AM x FM x CM		8.2 kg
Lifting index		1
Status		Not Risky

Appendix 60: NIOSH Lifting Equation calculator -Job Analysis Sheet for job K

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	Job K



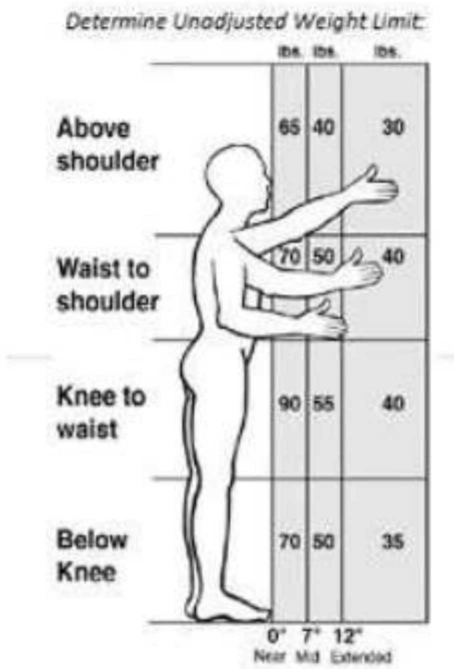
NIOSH Lifting Variable	**Value**	**Multiplier**
Horizontal Location (**H**) cm	30	0.83
Vertical Location (**V**) cm	150	0.77
Travel Distance (**D**) cm	50	0.91
Angle of Asymmetry (**A**) Degrees	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	1	1
Frequency - (**F**) Lifts/hour	12	0.85
Load lifted (**L**) kg	19.3	19.3 kg
Duration (**D**) (1-short, 2- Moderate, 8 - long)	8 hrs	
RWL = 23 xHM x VM x DM x AM x FM x CM		11.5 kg
Lifting index		1.68
Status		Risky

Appendix 61: WISHA Lifting Calculator -Job Analysis Sheet for job K

WISHA Lifting Calculator -Job Analysis Sheet

Job No	Job K

Actual weight (kg)	19.3 kg
Unadjusted Weight Limit (lb)	50
Unadjusted Weight Limit (kg)	22.7
Lifts per Minute	12/hr
Hours per Day	8 hr
Twisting	0
Horizontal distance (cm)	30
Vertical distance (cm)	50



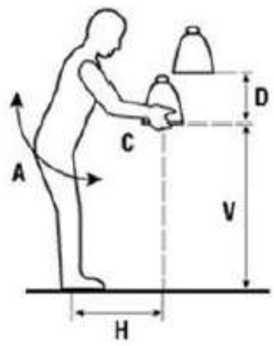
Unadjusted weight Limit (kg) x	22.7
Twisting Adjustment	1
Adjusted Weight Limit (kg) x	22.7
Limit Reduction Multiplier	0.85
Weight Limit (kg)	19.3

Actual Weight(kg)/	19.3
Weight Limit(kg)	19.3
Lifting Index	1
Status	Not Risky

Appendix 62: NIOSH Lifting Equation calculator -Job Analysis Sheet for job L

NIOSH Lifting Equation calculator -Job Analysis Sheet

Job No	Job L



NIOSH Lifting Variable	Value	Multiplier
Horizontal Location (**H**) cm	50	0.5
Vertical Location (**V**) cm	150	0.77
Travel Distance (**D**) cm	50	0.91
Angle of Asymmetry (**A**) Degrees	0	1
Coupling (**C**)(1 -good, 2- fair, 3 - poor)	1	1
Frequency - (**F**) Lifts/hour	12	0.85
Load lifted (**L**) kg	6.9	6.9 kg
Duration (**D**) (**1**-short, 2- Moderate, 8 - long)	8 hrs	
RWL = 23 xHM x VM x DM x AM x FM x CM		6.9 kg
Lifting index		1
Status		Risky

Appendix 63: Details of the participants of the case study

Age (years)	Height (cm)	Weight (kg)
30	160	50
24	160	53
25	162	59
32	163	60
33	175	64
36	182	73
23	171	68
31	156	65
33	166	52
39	164	59
22	169	74
23	174	51
24	161	68
26	160	54
37	160	47
26	159	52
19	173	59
18	173	65
37	158	50
19	169	48
40	161	53
25	168	57
35	150	50
37	164	58
40	165	52
29	158	48
26	160	54
20	166	50
28	166	68
26	165	66
32	152	47
31	153	66
21	161	64
31	173	76
39	160	48
20	154	51
28	163	54
35	161	48
33	167	56
18	163	57
38	178	60
31	174	53
29	166	61
40	169	64
34	163	60
25	166	62
25	176	68
18	162	68
32	165	54
25	163	58
29	178	69

Cntd…

Age (years)	Height (cm)	Weight (kg)
22	168	60
24	167	66
30	164	53
39	156	56
25	161	53
35	160	56
33	163	57
28	160	59
26	168	64
49	167	68
38	165	57
25	171	57
30	151	47
26	164	68
26	168	70
33	155	56
19	163	48
31	160	50
22	169	73
23	159	52
22	150	51
37	165	81
42	183	80
40	172	61
32	177	66
26	159	60
26	169	51
27	168	50
18	158	51
40	151	50
27	178	68
25	171	70
26	172	80
30	167	69
39	166	65
21	160	48
29	159	53
34	178	62
33	157	61
20	165	71
23	155	56
38	169	68
20	160	50
22	164	55
24	163	59
38	171	58
21	164	58
23	160	47
43	157	52
24	170	57
27	164	78
35	157	51
40	170	52

Cntd…

Age (years)	Height (cm)	Weight (kg)
22	163	50
23	168	66
37	169	66
32	156	64
22	154	47
20	165	59
30	154	70
31	163	67
46	160	55
20	159	55
19	166	53
22	177	72
31	156	54
31	166	63
37	151	56
30	178	61
30	150	45
21	155	48
20	165	58
24	168	60
32	163	68
28	163	56
28	180	70
37	160	59
35	159	55
32	168	61
30	173	70
40	171	61
29	181	66
22	163	68
21	152	51
32	170	81
33	164	61
26	162	50
19	162	47
37	168	69
22	161	60
27	179	80
33	165	57
28	180	70
27	165	56
39	173	66
23	165	54
35	180	73
30	159	57
21	168	57
51	158	60
31	163	66
28	165	58
33	166	73
19	161	59
23	170	69
37	169	63

Cntd….

Age (years)	Height (cm)	Weight (kg)
34	148	49
30	158	54
26	160	55
29	177	82
39	168	68
21	166	66
36	161	54
24	168	58
23	159	54
22	163	62
29	172	66
27	158	58
40	158	55
29	168	53
26	163	55
29	166	59
20	160	51
34	150	53
40	157	64
22	160	59
32	166	58
25	166	55
36	148	52
20	166	59
26	149	55
40	159	53
21	158	50
25	168	48
21	160	50
34	166	66
24	163	65
22	176	53
21	164	65
20	160	53
22	162	57
19	160	46
31	181	71
26	167	61
21	160	74
21	160	70
24	163	56
18	167	62
30	172	65
28	154	52
25	182	64
24	176	52
20	172	67
30	172	84
21	161	62
25	168	55
20	160	54
41	164	51
23	165	57

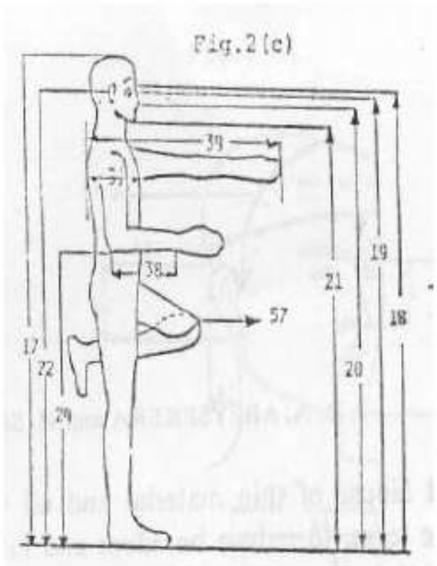
Cntd….

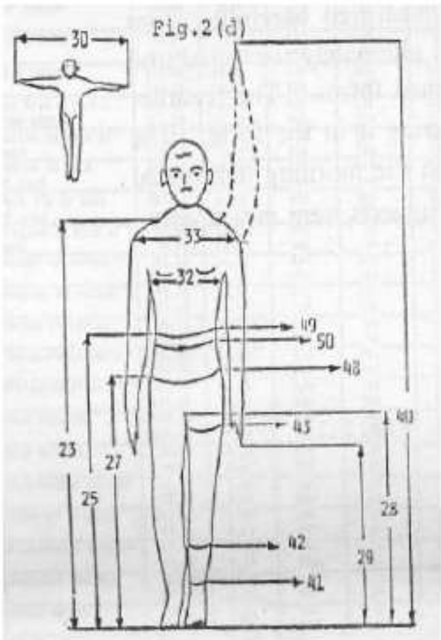
Age (years)	Height (cm)	Weight (kg)
24	165	62
24	160	61
26	166	64
33	152	50
32	158	50
19	159	52
18	158	49
35	152	55
19	160	70
27	170	69
19	160	56
26	155	47
32	174	65
29	162	58
31	167	72
40	162	50
22	164	50
38	160	50
49	166	68
39	163	55
50	168	67
30	168	68
36	159	69
37	165	66
23	168	59
19	168	60
28	155	58
23	161	51
27	168	59
32	166	57
34	163	62
40	167	76
37	178	70
23	165	61
38	165	50
21	179	58
20	163	56
24	167	65
25	163	50
31	159	65
29	184	77

Appendix 64: Standing anthropometry data of Sri Lankan population [45]

Standing measurements

No.	Measurements	Mean (men)	Standard Deviation (men)	5th per centile (men)	95th per centile (men)
17	Stature	1639.01 1422.11	63.51 58.77	1536 1426	1746 1517
18	Masion height	1555.19 1439.50	62.07 59.56	1440 1343	1539 1534
19	Eye height	1535.31 1414.39	62.19 58.87	1429 1323	1634 1520
20	Subnasale height	1503.25 1388.70	61.70 58.46	1403 1295	1601 1488
21	Menton height	1435.29 1327.45	59.32 56.72	1342 1232	1537 1474
22	Trylon height	1507.12 1396.68	60.40 57.69	1412 1304	1691 1490
24	Elbow height	1014.04 941.45	70.04 62.11	929 873	1100 1015
31	Chest depth	170.60 161.53	19.87 19.40	146 136	204 193
38	Elbow wrist length	276.31 251.91	34.84 33.98	247 225	302 276
39	*Forward reach*	*817.02* *75737*	*59.63* *45.40*	*747* *692*	*807* *828*
57	*Knee fully Bent circulerence*	*391.68* *355.77*	*25.57* *2486*	*350* *320*	*430* *395*





No.	Measurements	Mean (men)	Standard Deviation (men)	5th per centile (men)	95th per centile (men)
23	*Shoulder height*	*1377.09* *1271.61*	*59.24* *53.99*	*1280* *1184*	*1472* *1360*
25	*Waist height*	*1060.24* *1012.79*	*64.35* *57.05*	*976* *931*	*1160* *1040*
27	*Hip height*	*971.91* *920.71*	*58.51* *75.94*	*885* *840*	*1062* *980*
28	*Crotch height*	*775.32* *776.24*	*48391* *60.90*	*707* *690*	*841* *846*
29	*Finger tip height*	*607.16* *571.28*	*38.77* *45.11*	*554* *504*	*669* *676*
30	*Span*	*1690.56* *1544.66*	*88.64* *98.93*	*1506* *1407*	*1816* *1670*
32	*Chest breadth*	*249.35* *224.77*	*26.80* *19.08*	*216* *199*	*283* *252*
33	*Ulacromial breadth*	*360.29* *331.49*	*23.10* *18.46*	*331* *300*	*402* *361*
40	*Upward reach*	*2083.74* *1912.78*	*115.19* *118.59*	*1947* *1775*	*2236* *2051*
41	*Ankle circumference*	*196.01* *182.18*	*14.84* *11.43*	*175* *165*	*220* *205*
42	*Calf*	*306.14* *299.48*	*27.40* *22.80*	*265* *252*	*350* *325*
43	*Thigh*	*459.24* *456.97*	*49.54* *46.98*	*395* *390*	*545* *540*
48	*Buttock*	*823.25* *832.92*	*56.55* *53.97*	*240* *250*	*930* *925*
49	*Waist*	*688.63* *634.44*	*68.16* *61.24*	*605* *555*	*800* *740*
50	*Abdomen*	*717.42* *727.16*	*70.38* *71.76*	*630* *620*	*855* *850*

Appendix 65: Details of the participants of the validation case study

Age	**Height**	**Weight**
30	160	50
24	160	53
25	162	59
32	163	60
33	175	64
36	182	73
23	171	68
31	156	65
33	166	52
39	164	59
22	169	74
23	174	51
24	161	68
26	160	54
37	160	47
26	159	52
19	173	59
18	173	65
37	158	50
19	169	48
40	161	53
25	168	57
35	150	50
37	164	58
40	165	52
29	158	48
26	160	54
20	166	50
28	166	68
26	165	66
32	152	47
31	153	66
21	161	64
31	173	76
39	160	48
20	154	51
28	163	54
35	161	48
33	167	56
18	163	57
38	178	60
31	174	53
29	166	61
40	169	64
34	163	60
25	166	62
25	176	68
18	162	68
32	165	54
25	163	58

Cntd..

Age	Height	Weight
29	178	69
22	168	60
24	167	66
30	164	53
39	156	56
25	161	53
35	160	56
33	163	57
28	160	59
26	168	64
49	167	68
38	165	57
25	171	57
30	151	47
26	164	68
26	168	70
33	155	56
19	163	48
31	160	50
22	169	73
23	159	52
22	150	51
37	165	81
42	183	80
40	172	61
32	177	66
26	159	60
26	169	51
27	168	50
18	158	51
40	151	50
27	178	68
25	171	70
26	172	80
30	167	69
39	166	65
21	160	48
29	159	53
34	178	62
33	157	61
20	165	71
23	155	56
38	169	68
20	160	50
22	164	55
24	163	59
38	171	58
21	164	58
23	160	47
43	157	52
24	170	57
27	164	78
35	157	51

Cntd..

Age	Height	Weight
40	170	52
22	163	50
23	168	66
37	169	66
32	156	64
22	154	47
20	165	59
30	154	70
31	163	67
46	160	55
20	159	55
19	166	53
22	177	72
31	156	54
31	166	63